THE

POPULAR SCIENCE MONTHLY.

MAY, 1875.

SEA-ANEMONES.

By Rev. S. LOCKWOOD, Ph. D.

EVEN in minds the most illiterate you will find a sort of philosophy, if you but look for it. Among the dwellers by the shore is a class known as Watermen. These men, with great irregularities of toil and idleness, obtain the support of their families wholly from the bounteous, though sometimes precarious, harvest of the sea. Often one finds among them men of the roughest mould, yet with generous natural gifts, but without either education or culture. Of natural phenomena, in a practical way, they are shrewd observers. They know a good deal, too, about many queer forms and strange habits belonging to the denizens of the deep. In their way, they are positive men, and real empiricists too—for, from their limited lookout, and their small stock of facts, they will generalize as broadly as do some scientists upon a few experiments. An old waterman, who could not read a word, said to us: "Sir, Nature works the same in every place. There's nothing on the land what isn't in the sea; and I've even seen ships in the sky!" Here, then, although not a little empirical, in our fisherman's philosophy was a splendid generalization. And how broad it was! It covered every province possible for human experience, in his conception—the earth, the sea, and the air.

And empiricism begotten of a spirit in no wise nobler, abounded in the elder science. Thence have come down to us those heated controversies on the supposed vegetable nature of the polyps that build the corals, and other similar structures in the great deep. And there was that temporary calm which set in upon that stunning clincher of that empiricist, who declared that the coral polyps were, and must be, plants, for—"I have *seen* the flowers!" And Sir Wiseman was true. And so was the fisherman true, when he said, "he had seen ships in the sky." Each in his own way had seen a mirage.

But that clincher would not stay clinched. As concerned their external forms, all admitted them to be sea-flowers. Still, these flow-

ers of the ocean would insist on behaving themselves in divers ways, looking strangely in the direction of sentient things, albeit their plant-like aspect looked contrariwise. Could Nature, just here, Janus-like, look two ways at once? Might it not be that these mysterious things were the habitants of a certain border-land of life? Another empiricism—a generalization as splendid as that of the fisherman. So in complacent wisdom they called them zoophytes, namely—

ANIMAL-PLANTS.—Time, and a love of truth, will set a good deal right that seems inveterately wrong. Even this brilliant compromise must yield to the verdict that accrues from the patient study of facts generously collected and carefully collated. So this Janus myth, the zoophyte, which had become a cant word in science, turns out to be of no value as representing a fact in Nature. Though flower-forms they were, yet they were really animate things, and capable of acts indicative of will.

Our object now is to say something of one of these flower-like types of marine life, namely, the Sea-Anemone. It is significant, as showing the suggestiveness of these creatures, that, however diverse the nomenclature of science may be in regard to them, it is often almost poetical, and the words used are always expressive, and even possess pictorial significance. De Blainville named them *Zoantharia*, from which comes Animal Flower. Dr. Johnson's term took a wider latitude, and, although quite formidable-looking, and not in the best taste, was very significant. He gave the name, *Zoophyte helianthoidea*, which is to say, the Sunflower-like animal-plant. In these terms the animal nature and the flower-like form are intended. The creature is really a polyp, a soft, almost pulpy, sac-like structure, with a fringe of tentacles, like a halo of rays, around the upper end; in the centre of the circular fringe, the mouth, or oral aperture, being situated. Hence it is often spoken of as an actinia, which really means possessing rays. The word is now worked into another word, *Actinozoa*, meaning rayed-animals, that is to say, animals with rays around an oral disk. But the term is used to designate a class; hence it includes all the polyps, those that construct coral, and the others. This class is again divided into several orders, one of which is named *Zoantharia*, or, as it is sometimes called, the Helianthoid polyps. It is in this order that the actinia proper is found; and, therefore, it is there that we must find our sea-anemone.

Having found for this pretty object, in a system of science, "a local habitation and a name," let us see if we can make out the structure of a sea-anemone, or, as it is often called, an Actinia.

Taken in the hand, the sea-anemone imparts a slippery feeling, and it seems to have the consistency of leather. To get at its precise form, look at the cut given of *Actinia rosea*, a British species. Now, please follow closely our description a little while. As the actinia erects itself, attached to a rock or stone, it looks like one of the purses

formerly fashionable, if one such could be made to stand of itself erect, and have the frill around the upper end to project in a circle. But we must be more particular than this. The upright part, that which is called by naturalists the column, is hollow, like a sack. Its base is really a sucking-surface, enabling it to adhere to any hard object. By this sucking base it can glide, or travel along, much like a snail.

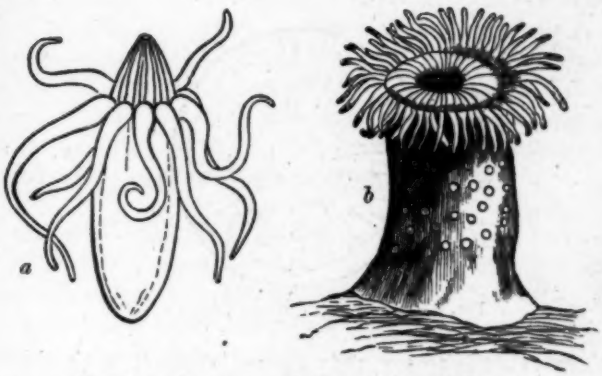


FIG. 1.—*a*, ARACHNACTIS ALBIDA; *b*, ACTINIA ROSEA.

And as it thus moves, it can keep its flower spread out, and its many tentacles in constant play—in fact, fishing on the way. Their movement is, however, very slow. Indeed, a "snail-pace" would be alarmingly fast for an actinia. We have watched them attentively, and have found that an inch in an hour was a very satisfactory performance. At the top is an opening, called the oral cavity, which, in the *rosea*, is surrounded just inside with a beading of little dots. This opening may be called the mouth, because the food is passed at this aperture into the stomach, which is a cylindrical sac, suspended below, and reaching about half-way down the great cavity of the column. Around the oral cavity, and external to it, is a plain surface, which is technically known as the "disk." Around the disk, on its outer edge, is the fringe of tentacles. Each one of these is a little hollow cylinder, opening into the great cavity of the column immediately under the edge of the disk. In fact, these tentacles, or feelers, connect with the interior of the stem of the Anemone, just as the fingers of a glove do with the interior of the same. We should also mention that, at the bottom of the sac, which is here called the stomach, is an opening into the general cavity. Now, around this suspended stomach, that is, between its outer wall and the inner wall of the column, is a system of compartments in series. These vary as to number in the different species. By looking at the cut showing a cross-section of an actinia's stem, we observe that six of these compartments are complete, and reach from the stomach to the walls of

the column. These six compartments are made by as many radiating vertical plains, whose edges on the one side are in contact with the inner walls of the column, and the edges on the other side touch upon the outer walls of the stomach. Between these compartments are others of less capacity. It is noticeable that these are, in like manner, formed of vertical plains, of different widths; and, further, that they are only attached on one edge, and that to the inner walls of the

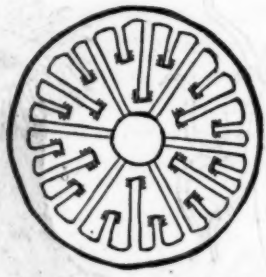


FIG. 2.—CROSS-SECTION OF AN ACTINIA-STEM.

great column, that is to say, they do not connect with the stomach. To understand the relation of these different walls of the compartments to the entire structure, a glance at the diagram will suffice, when it is borne in mind that the transverse section, thus represented gives also a section of the inner cylindrical sac, or stomach.

The upright walls of these compartments which we have described are known in science by the name mesenteries. Of what use are they? The most obvious service they perform for the animal when erect is, as we think, the stiffening of the structure. And this is done at will, as if it were a sort of erectile tissue. Now, as the cardinal plains connect both the inner and the outer cylinder, that is, the stomach and the column, it will be seen that the efficiency in the direction of imparting strength is considerable. The column is by so much the more strengthened, as it has the more of these upright planes or septæ attached to it by one of their respective edges.

But it is in these compartments, and on the mesenteries themselves, that the origin of life for the actinia's progeny begins—for there the ova and the spermatozoa are found. On the mesentery-walls are borne in series certain reddish bands. These are the reproductive organs, and contain the ova and the spermatozoa. Generally actiniæ are what the botanists call diœcious; that is, the ova are found in an individual—that we may call the female; and the spermatozoa in one that we may in like manner call the male. As to the time, and even the method of propagation, mother actinia is very capricious, there being, so far as our observations may determine, no regularity, but at the right time doubtless, for her convenience, the actinia evicts her young. Usually these are discharged at the mouth.

They are tiny little things, clad with cilia, with which they move freely in the water for a little while, then settle on some stone, and give themselves up to a sedateness worthy the parent that gave them birth. It often happens that mother Anemone sends out her little ones in a very rough way into the world. In fact, they are introduced into actinian society sadly *sans ceremonie*. From the mesentery chambers are certain little ducts which open into the neck of the orifice, which we have called the mouth; and this orifice, it will be remembered, is directly over the open stomach. So it sometimes happens that when one actinia is sending out a litter of her babies from the mouth, she, just at that very moment, takes a notion to empty her stomach of the indigested leavings of her last meal, so that these indigesta and two score innocents are evicted in a dreadfully execrable and unmeally-mouthed manner.

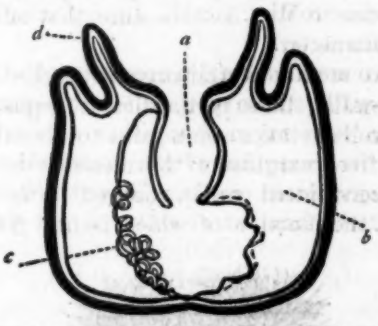


FIG. 3.—VERTICAL SECTION OF ACTINIA.—*a*, Stomach-sac; *b*, Mesentery; *c*, Craspedum; *d*, Tentacle.

We must now notice a remarkable apparatus known as the lasso-cells. It has been repeatedly observed that an actinia has a stinging, or, as it is called, an urticating power over the tissue of other animals. Now, there are in different parts of the body of an actinia innumerable cells, from which, especially the cells on the tentacles, it can dart an invisible thread. The microscope can see it, and has made known its structure. In some species this delicate thread thus shot out is a marvelously-complex affair. It is coiled up, and when necessity urges, at the will of the animal, it is darted like a cord from a spring-trap. Now, this is just the simplest part of it; for, strange to say, when this thread is shot forth, just at the striking instant, out of the sides of this invisible thread other threads or snares spring, and these last are barbed. What a wonderful mechanism is this!

Let me invite you to a sight I have many times beheld. I have in captivity a hungry sea-flower. Knowing well what suits its palate, I take a delicate morsel like a pilule, and let it fall into the water. It descends upon the waving petals, or tentacula, on the point of one of which the pretty creature has caught it in an instant. How delicate the adjustment upon its more than fairy fingers! For a few moments it is

balanced with the nicest poise on that dactylic petal. Ah! a voracious and unmannerly little bummer of a minnow sees the delicious morsel, and makes a rapid dash to snatch it from my pet. "Good! good! Well done, my bonnie!" I did not see the slightest motion of that indignant flower-creature; yet assuredly there was a movement, and an effective one, too: for the zoophyte had shot one of its invisible shafts; and the ichthyic thief dashes off like one frantic with pain. Is he hurt? Likely. His is an urticated experience. He is stung in the snout! See how he seems to shake his nose! He fairly seems to sneeze again, and actually conducts himself much like a puppy that, uninvited, has put his nose into a bowl of hot soup. Ah, ha! He is rubbing his fishy proboscis against a frond of sea-lettuce. Perhaps the salad may cool his burning pain.

Mr. Fish soon recovers his equanimity of mind; and it is observable that his deference to Mrs. Actinia since that affair has been of a decidedly distant character.

But we return to mention certain organs attached to the free edges of the mesentery-walls, those perpendicular septæ, or membranous partitions, which we have taken some pains to describe. Says Nicholson: "Along the free margins of the mesenteries there also occur certain singular convoluted cords, charged with thread-cells, and termed 'craspeda,' the function of which is not yet understood. It

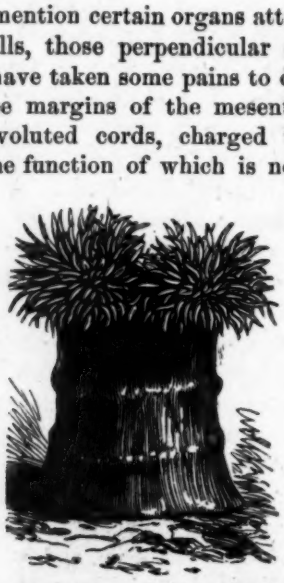


FIG. 4.—METRIDIUM MARGINATUM.—Fringed Actinia (*expanded*).

is believed, however, that the apertures, termed 'cinclides,' in the column-walls of some of the *Actinidæ*, are for the emission of the craspeda." Now, some observers say that they have seen these urticating phenomena take place from the side of the column of an actinia. Is it not, then, very likely that herein is the function of the craspeda? These "cinclides," or openings in the walls of the living column, are the portholes of the little tower, whence the "craspida"-like archers launch their invisible shafts.

That is an enviable experience when one is favored with the dis-

covery of one of Nature's secrets. We recall one such made in 1858 or 1859. Though we at that time prepared an account for publication, yet it never saw the light. In order to refresh our memory, we to-day have taken from our desk this old manuscript, and given it a perusal. We had among our aquarian pets a fine fringed actinia, *Metridium marginatum*, from Newport. To our glad surprise, we noticed one day that, as it adhered to the glass side of the tank, it was surrounded by a number of tiny young ones. The question was, where did they come from? That they came from the ova I had weighty reasons for doubting. So we set ourselves to find out, if possible. One day we were watching this anemone as it was gliding on the glass. Of course, the entire base was moving. But no—that is just where we at first were in error, for there was a little speck of its base that would not go along with the rest. There that little bit of the sucking-base stuck and held its place stubbornly. The great base kept at it—pulling, as it seemed, until a mere thread-like shred of matter connected the main mass and this little stubborn, speck-like remnant. And that connecting shred stretched like a thread of India-rubber. For nearly an entire day did this sort of thing continue, when at last the shred snapped, and the one part was drawn up into the base and the other part into the adhering speck or fragment. With our pocket-lens, we watched that tiny bit which had seceded from the body politic, or rather, from which the body politic had itself withdrawn. It soon gathered itself up into a plano-convex speck. The next day we observed a depression setting in at the convex point. In a day more we detected movement. It was dividing, and there was a pulling in two directions. This did not last over a day, and there were now two specks instead of one. In about three days, at top of each, five little tentacles appeared, and a tiny mouth. Wonderful to say, each was a young actinia. And

Fig. 5.—Fringed Actinia (*closed*).

how strangely begotten, too! Sloughed off—actually exscinded from the base—a veritable bit of that dear old mother; not bone of her bone, since bones she had none; but verily flesh of her flesh. This was, indeed, to us a new sort of fission. How we did watch that pair of self-made twins! Very diminutive they were, truly; but very great pets for all that.

These young actinia very rapidly increased in size, and soon had doubled the number of their feelers. Supposing that this argued an increase of feeling on their part, we found ourselves feeling an increase of interest in their ways and welfare. Just as this mutual understanding had been established, an incident occurred which filled us with anxiety. The mother-actinia began gliding back toward our little ones. That firmly-adhering base, sticking fast as the boy's sucker with which he lifts a brick, came slowly but surely, advancing toward her children. On, and on, now she is right upon them! Good-by, my twin babies, it is all-day with you now! That sucker of a mother has taken you in beyond all hope of redemption. How we did wish that that cruel parent would move on and let us see our pets again, even if dead! But no, now she would not move at all; and for nearly a day she retained that position. At length we detected movement—the gliding had begun. But, oh, how provokingly slow it was! Ah! we begin to see them at the peripheral edge of that mother's base. How flat the poor things look! No wonder, such a squeezing maternal embrace as that was. They are fairly out now—dead! dead! See, their little tentacles are protruding. It looks as if they were in a hurry to shake out their crumpled frills. Well, well, they have come out of this singular occultation as brilliantly as ever emerged a binary star.

The question whether these beautiful creatures have a nervous system seems not settled. That they manifest phenomena indicating a will, cannot be doubted. On one occasion my pets were all sulky, like "Jack in the doldrums." Every one was closed, which means it had shriveled up into a mere gelatinous lump. Each one in this condition had a disgusting look, resembling nothing so truthfully as a

FIG. 6.—ANTHEA CEREUS (*Opelet*).

ripened boil when the fetid core is ready for extraction. And we have often seen even this repulsiveness intensified, by evolving in threads a white, stringy slime, that peculiar mucous lining of which, in parts at least, the creature often takes occasion to divest itself when in repose. (*See* cut of Fringed Actinia closed.)

As above, when in repose, these sea-anemones look like clots of gelatine, and, as many of the actinia are very small, we have known

fishermen who have handled them, when adhering to oysters, for years, and never knew that they were aught else than spots of slime. Once, when out on the shore at a very low tide, and busy overturning stones, in search of creatures thus concealed, a fisherman, wondering what we were about, came and accosted us:

Fisherman—"What have you got, mister?"

Self—"Some little sea-flowers;" and we pointed to certain little hemispheres of pellucid but limpid pearl, on a stone held in our hand.

Fisherman—"What! them grease-spots?"

Self—"Yes. And you should see them when the tide's up. Then every one opens into a little flower. They're only shut up now."

With an expression that indicated doubt of our veracity, or sanity, Piscator turned away, muttering as he left, "Guess you'd better shut up, my blossom!"

However, we took our "grease-spots" home, proud enough of them. After time given for rest they came out finely. Pretty things they were. There was one especially, over which we had both joy and sorrow—the one to have found it, and the other when it died. It was a wee but winsome thing, about a third of an inch when unfolded, and all parts of it, column, and disk, and petals, were each and all of a soft, limpid emerald. Oh, we thought, if that could be transformed into a hard substance, what a gem it would be! That was the only time we ever saw an entirely green anemone. The green opelet of Great Britain is only so as to its tentacles, and even these are tipped with red. We have often obtained from the rocks in the East River very pretty small anemones, of an orange hue.

Generally the sea-anemone will not spread her beautiful form in a bright light. Often, when all seemed sulky and there was a general collapse, we have restored the whole coterie to good-humor, simply by covering up the aquaria for an hour or two, and then uncovering, when the flowers will fully open. It was a great transformation to see, when this change took place with our favorite—a fine, large, fawn-colored *Metridium marginatum*, obtained from Newport. When in healthful expansion it was larger than a good-sized dahlia; and although of a subdued neutral tint, yet in form and color we thought our marine-flower the superior of its terrestrial rival.

Somewhere we read the lucubration of a philosopher that there was no humor in Nature, but all was serious. The observation struck us as very learned, but very silly. No humor in Nature? Nonsense! Come out from your candle-light cogitations unto some real observations in the sunny light of Nature's beaming face, and I can show you humor. Ay, fun, if you will—yes, even practical jokes. A large actinia took a notion to swallow a large scallop, which it had captured. After considerable stretching it got the bivalve down into its stomach, and in due time the contained mollusk was digested. But what about the shell? Why, this—it could not get it up again! It was a double

disaster—literally as to the scallop, and metaphorically as to the polyp: both were sadly taken in. Actinia now looked very serious—comically so—like one in an evil strait. Perhaps it felt as bad as a hen-pecked subject, for it had got itself around a pecten, and a *pecten maximus* at that. If a guest at tea should swallow the tea-saucer, matters would look alarming. And this bolted scallop was as big as a saucer. The effect upon the actinia's looks was ludicrous, since there was a narrow, bulging, equatorial belt, strongly significant of an undue centrifugal force in activity at that place. Get rid of the saucer it could not; so it seemed, with a saucy air, to have made up its mind to resort to an expediency that should fairly checkmate the strange exigency. And this expediency was a change of base. In fact, it transformed its old base entirely. Tentacles grew out around it, an oval aperture appeared, and, in a word, it became a double actinia, and the large scallop shell was made a double base, and was accepted ever after as the demarcation of the two individualities. No fun in Nature? If this, despite a smack of sauciness, was not a practical joke of the first water, then bring out your specimen-brick, old Sober-sides!

But the time is up, and so much must be left unsaid. In the cuts is the white Arachnactis, a baseless actinia, which, stuck in the mud, waves its few snaky tentacles about. And there is the waxy Anthea, or opelet, with its snaky or gorgon hair. But we must stop, without telling of the singular varieties of forms, and the rich diversities of tint and color, and the sometimes queer, yet normal functions performed by these marine animal mimics of the floral structures of the land.

THE FIRST TRACES OF MAN IN EUROPE.

By Prof. ALBRECHT MUELLER.

TRANSLATED FROM THE GERMAN, BY PROF. JOSEPH MILLIKIN.

II.

WE have been concerned heretofore with the human and animal remains of the older Diluvium. We come now to the upper and more recent layers of that formation.

In these, the formerly so abundant remains of the cave-bear are wholly wanting, those of the mammoth very rare. The common animals are the giant-elk, primitive ox, aurochs, horse, chamois, steinbok, moose, monkey, and various species at present confined to arctic and high Alpine and Pyrenean tracts. The characteristic animal of the time, however, is the *reindeer*, heretofore absent or very rare, and hence the name—the Age of Reindeers.

The continued prevalence of a northern and Alpine fauna in the

lowlands of Europe, proves the continuance of the severity of climate; we are still dealing with the Ice period, or probably with a second ice-period, as many infer from the peculiarities of the more recent drift. Of course the retreat of the glaciers of this later Ice period—glaciers apparently less in mass and extent than those of the former one—would produce fresh floods and all the phenomena previously explained as the results of such floods.

Men were still troglodytes, but also to some extent lived out-of-doors in so-called *stations* at the foot of sheltering cliffs. The domestication of animals was not yet practised, even the reindeer being used for food only, though this is disputed by some writers. Of the use of metals there is not a trace. This age is shown by every indication to be separated from our own, the historic age, by not less than 10,000 years, as to its initial point, at least, for some writers believe it to have been continued until the beginning of historic times.

The knives, axes, and spear-heads, are still rough-worked, but more carefully and skillfully than before. The material for them was brought from considerable distances; those found in Belgium, for instance, being made from flint-bowlders found in the chalk of the Champagne district. Very many kinds of implements were in use. The pieces of iron-stone found among them were probably used there, as they are now, by many tribes, for painting the face and figure. Bright stones, shells, and the teeth of animals, were perforated and strung into necklaces and bracelets—personal vanity thus anciently asserting itself. Skins and furs were used for clothing. Needles of horn and bone, and pieces of horn and stones manifestly used for smoothing down the seams, are often met with. The dead were buried at full length in caves.

The station at Solutré, department of Saône-et-Loire, is rich in memorials of this remote age, such as carefully-wrought articles of flint, and bones of the species named, especially of the reindeer; and near by is a burial-cave in which are several perfectly-preserved skeletons, with skulls of the Mongol type, according to Dr. Pruner Bey. In this instance the bodies of the dead were inclosed between flag-stones.

Pottery had now come into use, but it was roughly made by hand and unburnt. The beginnings of art are now met, as in pictures upon bone, ivory, and slate, of the mammoth, aurochs, horse, etc., and even sketches of the human figure. In some of these drawings, shadows are rudely but not badly shown by peculiar linings. At Bruniquet, also, in the department of Tarn-et-Garonne, such engravings of the mammoth and reindeer have been found.

One of the most interesting collections of relics of this age was found in the Station de la Madeleine, in the department of Dordogne. Bones and flints from another locality seem to show the marks of an iron hammer.

The cave of Cro-Magnon, in the same department, was rich in human skulls, skeletons, and handiwork; among other articles were perforated shells, evidently once worn in necklaces. Contrary to rule, bones of the mammoth were here associated with those of the reindeer.

At Chavaux, Belgium, was a deposit of remains, the disposition and other indications of which almost compel the belief that the place was the scene of a cannibal feast. The human skulls and bones are all of young women and boys, witnessing to a decided preference for young and tender flesh on the part of our anthropophagic ancestors. These bones were split open longitudinally, as was the custom with those of animals, for the extraction of marrow. This and similar discoveries in other caves throw a singular light upon the habits and culture of the men of this time.

Many Belgian caves, and notably that of Chaleux on the Lesse, yield large collections of mammal bones and stone implements.

The digging of a mill-race through a peat-bed at Schussenried, a village not far from Ravensburg, revealed a station very rich in archæological relics of this age. It was probably little more than the rubbish-heap of a station near at hand. There was here a profusion of flint articles, and bones and antlers of the reindeer. The mosses and snail-shells of the peat of this vicinity belong, like the mammals mentioned, to arctic and Alpine species, and are thus another evidence of the rigors of the climate of that time.

A station at Salêve, near the Swiss frontier, contains reindeer-bones of the Reindeer age, and stone axes, and human bones of the preceding Age of Mammoths.[1]

Switzerland and the Rhine valley below Basle have furnished but few relics of the Reindeer age, while France has many localities yielding quantities from both this and the Mammoth period, which are the two earlier Stone ages, the third and last of which will be next discussed.

So far, we have found human bones, skulls, skeletons, axes, knives, spear-heads, needles, ornaments, etc., of the periods discussed, in almost every country of Europe—in Greece, Italy, Spain, Portugal, and the soil of classic Rome itself, as well as in the northern regions.

THE AGE OF POLISHED STONE.—This name has been given by French writers to the third era of prehistoric human existence, on account of the characteristic smoothness and polish of the stone implements.

The distribution of land and sea, the relief of the surface, the climate, and the flora and fauna of this age, were substantially as they are now.

Among its oldest memorials—and the age probably ended about

[1] After a new and critical study of this deposit, Prof. Rütimeyer believes it to be a confused mingling of remains from various epochs.

B. C. 5000—are the Kjökken-möding[1] of Denmark, found at stations adjacent to the sea, and consisting of immense collections of empty mussel and oyster shells. Similar heaps are found in the United States.[2] The late Prof. von Mulot made careful studies of those of Europe, and the reader is referred to his valuable works for details. Comparatively barren as we have stated Switzerland to be in human memorials of the two preceding eras, it is the land richest in those of this age; for to it belong the oldest of the pile-dwellings found in most Swiss lakes and lacustrine peat-beds.

They were first discovered at Meilun, on Lake Zurich, during the winter of 1834–'35, when the level of most Swiss lakes was exceptionally low. Of course the mere existence of piles in our lakes had long been known to fishermen, but their real meaning and their significance for science was there first recognized by that keen-witted observer, Dr. Ferdinand Keller, of Zurich. We can offer nothing like an adequate description of these remarkable lake-villages, and shall speak of them only with reference to the indications they afford as to the man of this as compared with that of former prehistoric periods.

In addition to the rough-worked implements heretofore so abundant, we now have smooth, even polished axes, etc., of various hard stones, especially of greenstone, a term including diorite, syenite, and the peculiar serpentine which the Italians call *gabbro*. These axes were in various ways, and sometimes very ingeniously, attached to bone, wood, or horn handles. Besides these larger articles are many smaller ones, made of wood and horn, with arrow-tips and spear-heads of flint, jasper, and rock-crystal, often made with remarkable skill and carefulness of finish.

With the Age of Reindeers ends the Diluvial period proper, of which most of the characteristic animals, the reindeer among them, were by this time extinct, or else had wandered to distant regions. Hence the absence of their remains in later formations. Evidences of the domestication of animals now appear for the first time. Pottery is still rude and unburnt, but ornamented with odd stripes and rows of dots. The pieces are mostly conical, the bottom being the truncated point. No trace of writing, drawing, or sculpture, is to be found—a fact the more remarkable in view of the existence of the works of art mentioned as belonging to the preceding age.

The literature of the pile-dwellings is already quite extensive. Keller, Desor, Troyon, Morlot, and others, have written valuable manuals, while Heer and Rütimeyer have given *in extenso* the results of their thorough study of the vegetable, animal, and human remains, found in these curious habitations.

Those of the age we are considering are found in the edges of many

[1] Literally, *kitchen-refuse-heaps*.—TRANSLATOR.

[2] They were capitally described in the *American Naturalist* for January, October, and November, 1868.—TRANS.

lakes, and in peat-bogs near Pfeffikon, Inwyl, Wauwyl, and Moossedorf. Often they are grouped into considerable villages, as on Lakes Constance, Neuchâtel, Geneva, Zurich, and Morlat. These dwellings are found not only in Switzerland, but also in Bavaria, Carinthia, Moravia, Pomerania, and Mecklenburg, in Germany; and in France, England, Ireland, and the north of Italy. Of these some belong to the Stone age, some to the Bronze age, which we will next describe, and some were inhabited during both the Stone and Bronze ages.

With the pile-dwellings are to be classed the cranochs or cranogues —artificial islands, built upon piles in the peat-bogs and lakes of Ireland; the burial-places of Monsheim, near Worms; and land-stations in wellnigh every country in Europe, as well as in Asia Minor, Syria, Palestine, Japan, Java, India, North Africa, Egypt, and North America. It must not be forgotten, however, that the polished-stone implements of some of these various localities may belong to later times, as there are now living tribes at about the grade of culture that was attained in the Stone age.[1] At Grand-Presigny, south of Tours, and at Charbonnières, in the Mâcon district, are places abounding with the nuclei of flint-boulders, and articles made therefrom in every stage of finish, with many spoiled in making—places evidently once devoted to this manufacture. Some caves in the departments of Yonne and Ariége show layers of loam upon calcareous tufa, the human and animal remains of each of which are exactly those of the successive ages we have discussed, viz., of the Mammoth, of the Reindeer, and of Polished Stone. That is, they constitute a succession of deposits, each with its peculiar animal remains, and hence offer the same kind of evidence as to their relative antiquity as do the older geological strata.

And like the earlier geological eras, the various ages of prehistoric human existence are not sharply defined and severed, each from the preceding and succeeding one, but one merges into the other by gradual progressions of thousands of years. Not only certain species of plants and animals, but entire races of man, have thus slowly vanished from off the earth, or retreated to lands far remote, while others have as gradually come in to occupy their places. Some animal species, as for instance Speller's *Borken-thier*,[2] the dodo, and the auk or great diver, have died out within historic times; others in very recent times, as for example the huge birds of New

[1] Long after metals were in common use among them, many ancient peoples (of which the Jews were one, as the Bible informs us) employed stone knives in all religious sacrifices, etc. The Indians of North America and the Greenlanders yet use stone implements exactly similar to those of the lake-dwellings.

[2] Literally, *bark-animal*, or bark-eater, as we would say in English. I am utterly at a loss for the English or scientific synonym. The best guess I can offer is that it is a Castoroid, or Castor proper—possibly the giant beaver of the species *Discopylus*. (*See* Dana, "Geology," pp. 562, 563.)—TRANS.

Zealand and Madagascar.[1] And there is going on before our eyes the sad spectacle of the extinction of some of the nobler savage races of men, incapable of persistence in life in an age like ours, opposed by the superior forces of European civilization.

From the beginning civilization has spread from the East to the West, and such is still its line of march, as illustrated by the Teutonic race's steady pressure into the ever-receding "far West." So, too, with the people of the pile-dwellings. They probably came from Asia to Europe some 6,000 or 7,000 years ago, being doubtless affected, as is every people, by the powerful modifying influences either produced or put in full play by such long and vast migrations. And the people who made the stone axes and the pile-dwellings is probably the same that reared the huge funeral piles known as *dolmens*.[2] A dolmen consists of two immense blocks of stone placed on end,[3] upon which a third is laid, forming a sort of table. The dead were buried beneath, with various implements and weapons at hand. How a people, without engineering skill and contrivances, could rear such masses into position, is a problem yet unsolved. They are found in Brittany, Southern France, Great Britain, Portugal, North Africa, Nubia, Palestine, and the East Indies, those of Brittany being the largest.

Thus, instead of the golden age, that fancy represents as lying far back in the race's childhood, we find the dull realities of a long Stone age, during which man endured all and more than all the perils and sufferings of the present.

And yet, for each of us, as years steal over us, the days of our own vanished youth are ever "the *good* old days."

THE AGE OF BRONZE.—The predominance of bronze, as the material of the articles found in the later pile-dwellings, has given to the fourth prehistoric human epoch its name—the Age of Bronze. While some of these lake-villages continued in use from the Stone age, others —usually those farthest out in the lakes—evidently originated in the Age of Bronze.

There is no longer room to doubt that the bronze articles of Switzerland were made near the places of their discovery, and were not brought from the East, according to the common view. Some of the very moulds in which they were formed have been discovered, and at Nantes the remains of a foundery have been plainly made out. Whether the bronzes of Northern Europe are of Phœnician origin is yet in doubt. Their symbolisms and religious adaptations are in favor of that view.

[1] To wit, the dodo, solitaire, moa (*Dinornis giganteus*), and *Æpiornis maximus*. (For description, *see* Dana, pp. 578, 579.)—TRANS.

[2] Or cromlechs.

[3] In some instances there are three or more uprights. The covering stone of one specimen is 18 feet long by 9 broad. In the Anglesea cromlechs are stones weighing 30 tons each.—TRANS.

The native origin of those of Switzerland is settled by the analyses of Prof. von Fallenberg; for, whereas the metal of Phœnicia, Egypt, and the East generally, contains lead in considerable quantities, that of Switzerland is of tin and copper only. So much artistic taste and mechanical skill are shown in these various articles—needles, rings, armlets, etc.—that many of them might be used by modern ladies without discredit to their work-boxes or toilets. But, in singular contrast to the Stone age, there is no relic of any portrayal of man or beast or plant. We meet, for the first time, with pottery turned on the lathe and well burned. Instead of dolmens we now have mounds, in which the dead are laid at full length, with weapons and ornaments by their side. Some localities offer indications that the burning of the dead was practised. Here belong the so-called Celtic mounds, and the Terremare or Emilian mounds near Parma abound in relics of this age. Rütimeyer and others show that, although the characteristic animals of this and the preceding age are identical as to their species, in this age the domesticated animals predominate, another evidence of advancing culture.

We may ascribe the introduction of bronze manufacture into Europe to a great race immigrant from Asia some 6,000 years ago, called *Aryas* or *Aryans*. And this Bronze age reaches to and overlaps the beginning of the historic period in some countries, and so includes the great epochs of the Assyrian and Egyptian Empires (B. C. *circa* 1500), and the earlier eras of the next succeeding Age of Iron.

THE AGE OF IRON.—The nearer we approach the present, with its rapid growths and changes, the shorter become the several ages into which we divide the history of man as to his physical surroundings and peculiarities, and the successive grades of spiritual and social development through which he has passed.

Last of the prehistoric eras is the Age of Iron, represented in some of the pile-dwellings and their contents, but best, and with least admixture from earlier and later times, in the station of La Têne on Lake Neuchâtel. This age considerably overlaps the historic period of several countries. We can but mention some peculiarities of its earlier portions.

In the determination of its initial and terminal points we must remember that the civilization of the East preceded that of the West by several centuries. There are many proofs that a considerable degree of culture existed at its very beginning. Mounds were still used for burial. Bronze, also, was yet in use, but iron as well. Pottery was now not only shaped on the lathe, but burned a good red. Manufactures in glass, gold, and silver, are found for the first time. In lonely mountain-places are yet found dross and the remains of iron-furnaces of the time. To be sure, this dross is sometimes ascribed to volcanic action, but it is met with where volcanoes never could have existed.

To the former part of this age belong the weapons found in the Tiefenau, near Berne, plainly indicating that it was the field of a battle fought some 600 years B. C. Of great interest, also, is the ancient city of graves near Hallstadt, where the Burgomaster Ramsauer and others found over 900 graves and an immense quantity of iron and bronze weapons. But, interesting as such discoveries are, they lie too far outside the special topic of our treatise to be further discussed.

If a name, descriptive of the age in which we live, be sought for, "the Age of Paper" is perhaps as good as any that can be discussed. If we name it not from its present but its near future characteristic, we may perhaps best adopt that suggested by an eminent geologist—"the Age of Steel."

Even this hurried retrospect of the various prehistoric ages makes prominent the fact that in Europe, if not over all the earth, humanity has progressed, with various temporary haltings, from beginnings very rude and, in some respects, almost animal-like—that it is only after the lapse of many millenniums it has attained its present high physical and spiritual development.

In the progress of these studies we have perhaps become the poorer by more than one fair dream's evanishing. We have not found —we could not find—either the lovely paradise of our first parents, nor the much-sung, much-blessed golden age.

But one thing, at least, such investigations secure to us—the conviction, namely, of the limitless perfectibility implanted by the Creator in the very germs and essence of all his creatures, and preëminently in man.

And this conviction it is that opens to the eye and hope the precious, the inspiring prospect of an ever richer, fairer development for races yet to come.

SCIENTIFIC PROPHECY.

PROPHECY is the prediction of an event—the declaration of something to come. When future events—either in the history of the world or in the life of man—have been foretold from no known data and from no law, the prophecy must have been divine, for none but God can know the future of man. When such events in the history of Nature and in the life of matter have been predicted from known data and from established laws, the prophecy is human and scientific. Every science in its growth passes through three stages: First, we have the stage of observation, when facts are collected and registered by many minds in many places. Next, we have the stage of general-

ization, when these well-ascertained and carefully-verified facts are arranged methodically, generalized systematically, and classified logically, so as to deduce and elucidate from them the laws that regulate their rule and order. Lastly, we have the stage of prophecy, when these laws are so applied that events can be predicted to occur with unerring accuracy. Astronomy is said to be the only science which has thoroughly reached the last stage. Other sciences are in various stages of growth. Electricity in some branches has reached the third stage, but in many branches it is still in its infantine period. Astronomy predicts eclipses, transits, occultations, for any period in the future, and the "Nautical Almanac" is the most wonderful example of prescient knowledge: a sailor may go away for a five years' cruise, and yet in this book he will find every event in the motion of the planets, the movements of the tides, the rotation of the moon, the eclipses of the sun, etc., faithfully and unerringly foretold. But astronomy has produced greater wonders than these. The planet Uranus was found to suffer from some slight disturbances in her path round the sun. Adams in England and Leverrier in France simultaneously and independently, from the known laws of gravity, predicted the existence and position of another unknown planet. Galle, of Berlin, directed by Leverrier, found the planet in the spot indicated, and it was called Neptune.

Newton, the grandest scientific man the world has perhaps ever seen, and the founder of the laws that led to the prophecy just narrated, in his investigations on light, predicted the fact that the diamond was formed of some combustible material—from its very high index of refraction. The combustion of diamond is now an ordinary, though expensive, lecture experiment. Light has given us one or two other scientific prophecies. Poisson, from theory, pronounced that, in the case of an opaque circular disk, the illumination of the centre of the shadow caused by diffraction at the edge of the disk would be precisely the same if the disk were altogether absent. Arago proved this to be true. Again, Sir William Hamilton predicted that in biaxial crystals there were four points where the refraction of the crystal upon an incident ray produced a continuous conical envelope. Dr. Lloyd took a crystal of aragonite, and, following Hamilton's directions, discovered what the mathematician had predicted.

Whewell predicted from theory that there must be a certain point in the North Sea, midway between Lowestoft and the coast of Holland, where there was no rise or fall of the water, because the crest or high-water mark of the tidal wave, and the trough or low-water mark of the same wave, reached the same point at the same time, but by different routes. Captain Hewett, R. N., found that it was so.

Electricity has its prophets. Faraday, examining Sir Charles Wheatstone's beautiful experiment on the velocity of electricity by means of a rotating mirror, said: "If the two ends of the wire in

Prof. Wheatstone's experiments were immediately connected with two large insulated metallic surfaces exposed to the air, so that the primary act of induction—after making the contact for discharge—might be in part removed from the internal portion of the wire at the first instant, and disposed for the moment on its surface jointly with the air and surrounding conductors, then I venture to anticipate that the middle spark would be more retarded than before. And if those two plates were the inner and outer coatings of a large jar or Leyden battery, then the retardation of the spark would be much greater." The experiment was not made for sixteen years. It was then shown as the explanation of the retardation of the current in our subterraneous and submarine wires.

Sir Francis Ronalds, with wonderful prescience, had in 1823—fifteen years before Faraday—suggested "the probability that the electrical induction which would take place in a wire inclosed in glass tubes of many miles in length (the wire acting like the interior coating of a battery) might amount to the retention of a charge, or at least might destroy the suddenness of the discharge." Faraday's prophetic vision and Ronalds's far-sighted knowledge are verified in every working cable. The accuracy with which our cable-repairers are directed by our electricians to the spot where the wire is broken, the exactitude with which the working speed of a cable is predicted, the unfelt and invisible supervision which is exercised over the care and maintenance of our telegraphs—even though they pass through distant countries and different climes—are evidences that electricity, in this particular field, is approaching the last and prophetic stage of its growth. This field is resistance, and Ohm is its prophet.—*Telegraphic Journal.*

THE CHEMICAL RADIATIONS.

By W. J. YOUMANS, M. D.

WITH that proneness to go wrong, which we notice in most things human, and which crops out in science as well as elsewhere, the art of making pictures by the chemical action of radiant forces has got a false name. This is all the worse, as it was at first correctly designated, and that too by him who had the clearest right to give the process a title. Davy and Wedgwood, early in the century, had labored to produce sun-pictures by means of the *camera-obscura*, but had met with little success. In 1814 M. Neipce, of Chalons, in France, took up the subject, and, in the course of ten years' assiduous work, he succeeded in a method of forming sun-pictures on chemically-prepared copper, pewter, and glass plates, by which the lights, semi-tints, and shadows, were represented as in Nature, and he also succeeded in

making the impressions lasting. In 1827 he sent a paper to the Royal Society, accompanied with specimens; but, as he kept the process a secret, the communication could not be received. The process, however, he named *heliography*, or sun-drawing, a term by which it was truthfully characterized. M. Daguerre, another Frenchman, had been working at the same problem, and in 1829 these two men, with a common purpose, formed a partnership to carry on their researches jointly. Neipce died before the work was matured, and Daguerre, very naturally, reaped the honor of it. The French Government bought his secret, paying with a life-pension, and promulgating it to the world, without restriction of patent, in August, 1839. The new pictures were at once known as *daguerreotypes*, and the mode of making them the *daguerreotype process*. These uncouth terms endured for a while, but were at length supplanted by the word *photography*, or *light-drawing*, which has become established. Yet the appellation is incorrect, and the error is as broad as the difference between light and darkness. It is not light that makes the picture, but dark radiations that are associated with it, and that have the peculiar effect of producing changes in certain chemical compounds.

Although photography, in its wonderful development as an art, belongs to the past generation, yet the knowledge of the chemical effects ascribed to light is as old as chemical science. The subject began to be inquired into, experimentally, about 100 years ago. In fact, like most other modern chemical results, it had not escaped the notice of the alchemists, but, like every thing else they discovered, it was subordinated to their mystical speculations. In the multiplicity of their manipulatory processes they stumbled upon a combination which they called *luna cornua*, or horn-silver, and which is now known as silver chloride. The alchemists knew nothing of its composition, but only that there was silver in it which had undergone a change. They noticed, however, that when this horn-silver was exposed to light it underwent a blackening, and, as they taught that "silver only differed from gold in being mercury interpenetrated by the sulphurous principle of the sun's rays," they concluded that this change, effected by light, was the commencement of the process by which silver was to be transmuted into gold.

It was in 1777 that the illustrious Swedish chemist, Scheele, published the first results of investigations upon the subject undertaken simply for the extension of chemical knowledge. He found that, when powdered *horn-silver* is spread over paper, and the colors of the solar spectrum are made to fall upon it, the powder in the violet ray turns black sooner than that exposed to the other colors. Senebier afterward showed that the silver chloride was darkened in the violet ray in fifteen seconds to a shade which required the action of the red ray for twenty minutes; that is, the chemical intensity of the violet ray was eighty times greater than the red.

The next step was one of great scientific importance, indicating, not only the differentiation of the different modes of action in the sunbeam, but the actual separation and isolation of the different agents. This took place just at the opening of the present century. It was shown by Sir William Herschel, in 1800, that, when the sunbeam is decomposed by a glass prism, as shown in Fig. 1, the heat is distrib-

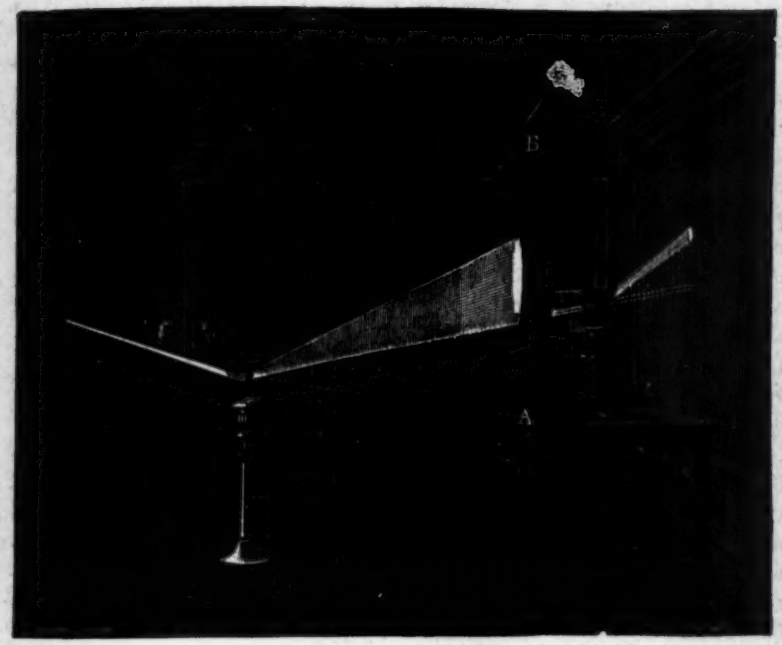


FIG. 1.—POSITIONS OF THE THREE SPECTRA.

uted unequally through the series of colors—is lowest in the violet, increases in the yellow, but is most intense in the red. This he determined by the use of delicate thermometers, and, in the same way, he proved that the thermal rays of the sunbeam are not all thrown into the visible spectrum, but are of such low refrangibility that they accumulate in the dark space below the red. There is therefore a spectrum of dark rays, producing heating effects, which, beginning at *A*, Fig. 1, increases in strength till it approaches the red, and then fades away in the upper region of the spectrum.

These results of Herschel were followed by the discovery of Ritter, made the next year (1801), that the chemical rays, which had been shown to be most active in the violet portion of the spectrum, were also thrown by refraction into the dark space beyond the violet. As a thermometer was the test in the case of heat, so an appropriate chemical substance has to be used to test the distribution of this force.

If a solution of silver nitrate is washed over a large sheet of paper, which is then placed upon the wall or screen so as to receive the spectrum upon its surface, and is also made to cover the space considerably above it, a transformation occurs where the radiations fall, producing a blackening which defines the outline of the chemical spectrum. It is now found that the chemical rays are more refrangible than the luminous, and that, while the darkening takes place in the colored spectrum, it it strongest in the violet of all the colors, and extends also through the dark space up to *B*, as shown in the figure.

It is now exactly 200 years since Newton published his "Optics," in which was described the capital experiment of resolving white light into its constituent colors by the prism. It was the first great step toward showing that what was regarded as perfectly simple turns out to be inexhaustibly complex; and every succeeding step of research, while clearing up some points, has led to others which are still unresolved. One thing, however, seems to be quite clear: the mode of action throughout the spectrum is fundamentally the same. There are three spectra, one of which, the thermal, takes action upon all kinds of matter; another of which, the luminous, acts only upon a certain special form of nerve-matter; while a third, the chemical, produces changes in certain compounds. Although the luminous force acts only upon the nerve of the eye to stir up a sensation, yet we know how infinitely complex and varied is the world of color that results. There is evidence that the dark thermal and chemical radiations are of equal variability and complexity, yet there can be no doubt that all these multitudinous effects are due to a single mode of action. The difference between the thermal and the chemical rays is simply the difference between the red and the green; that is, a difference of wavelength and degree of vibration.

The unequal distribution of the forces of the spectrum is well illustrated by Fig. 2. The middle curve shows the varying intensity of the luminous force. The maximum is at *B*, in the yellow space; and from this point the intensity of the light rapidly declines each way, its extent being shown by the space shaded with oblique lines. The curve *A*, with the vertical lines, represents the position and varying force of the heat; and the curve *C*, horizontally shaded, exhibits the distribution and unequal energy of the chemical force. The three maxima are widely separated as if there were some antagonism among them, and it is noticeable that where the light is strongest the chemical force quite disappears. Different prisms give somewhat different effects but do not change their order.

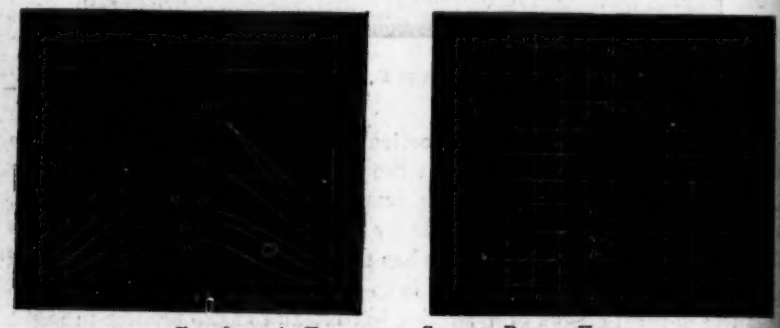
It thus appears that, so far from light being the agent which produces sun-pictures, the intensest light is powerless upon the chemically prepared plate. It looks as if the illumination neutralized or extinguished the chemical energy. Nevertheless, light and the chemical force are so intimately associated in reflection and refraction that

the colors become the guides of the artist in conducting his processes. When a person sits before the operator's camera, ready to be "taken," the radiations which are reflected from his face into the instrument, and collected to a focus by the lens, form three pictures, one behind the other, the thermal, the luminous, and the chemical image. The luminous image is visible upon the ground-glass plate, giving all the

FIG. 2.—INTENSITIES OF THE FORCES OF THE SPECTRUM.

colors of the object, but the chemical image is now blurred, and the focus has to be readjusted so that the chemical picture will be clearly and sharply defined; but, as this image is invisible to the operator, he has to make his readjustments by rule. As he cannot reproduce the colors in the photograph, he has to substitute for them tints and shades; but the chemical force is so unequal in the different colors that the natural effects of gradation in tone and shade are not brought out in the picture. This is one of the embarrassments of the process. From the representation in Fig. 2, we should infer that blue colors would act energetically upon the photographic plate and the yellow and red feebly, or not at all, because the chemical rays abound in the former and are absent in the latter. Of this false working of lights Prof. Vogel says: "Blue generally works clear, yellow and red work like black. The yellow freckles appear, therefore, in a picture as black spots, and a blue coat becomes perfectly white. Dark-blue flowers on a light-yellow ground produce in photography light flowers on a dark ground. Red and also fair golden hair become black. Even a very slight yellow shade has an unfavorable effect. A photograph from a drawing is often blemished by little iron-mould specks in the paper, invisible to the eye. These specks frequently appear as black points. There are faces with little yellow specks that do not strike the eye, but which come out very dark in photography. A few years ago a lady was photographed in Berlin whose face had never presented specks in photography. To the surprise of the photographer, on taking her portrait, specks appeared that were invisible in the original. A day later the lady sickened of the small-pox, and the specks, at first invisible to the eye, became then quite apparent. Photography in this case had detected, before the human eye, the pock-marks, very feebly tinged yellow."

The chemistry of light first became, in the full sense, a branch of science capable of thorough investigation when Dr. Draper devised a method of measuring the force of the chemical rays, and thus brought the subject within the sphere of quantitative research. He showed that these rays are absorbed in the chemical combination, and that the rate of absorption corresponds to the amount of chemical change. He applied mixtures of chlorine and hydrogen gases for this purpose, which combine under the action of the chemical radiations, the measurable rate of combination becoming the index of radiant activity. Professors Roscoe and Bunsen subsequently employed sensitive papers, which were blackened in certain times to certain shades, as measurers of the chemical force, and these were used at the Kew Observatory,

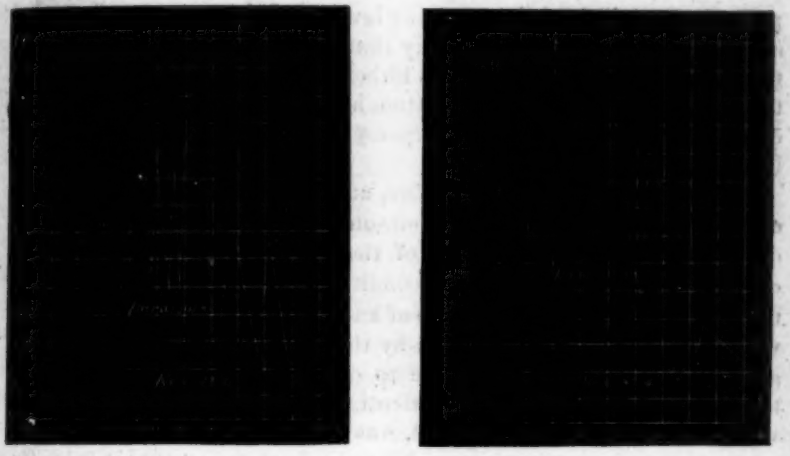


FIGS. 3 AND 4.—VARIATION OF CHEMICAL RAYS AT KEW.

near London, to trace the variations of chemical activity in the solar rays. For, as the chemical force is not light, neither does it follow the laws of light in producing its effects. Dr. Draper had previously shown that, as we go southward toward the equator, and the light increases in brilliancy, there is an increasing interference with the chemical rays, the yellow space of no-chemical action widening with the progress southward. It is also well known that there is much greater difficulty in obtaining good photographic pictures under the full blaze of a tropical sun than in our own latitude. The investigations at Kew were accordingly directed to the variations that the chemical rays undergo at different hours of the day and at different seasons of the year. The graphic diagrams, Figs. 3 and 4, show the results that were arrived at in 1866. The curves exhibit the rise and fall of the average monthly chemical intensity with the hour of the day, from 6 A. M. to 6 P. M., throughout the year. We see from these curves that the maximum of chemical action occurs at twelve o'clock, and that the forenoon rise and afternoon decline are very nearly equal, while the chemical intensity of July is fully seven times as great as in December.

The statements that have been made that in Mexico, where the light is very intense, from twenty minutes to half an hour is required

to produce photographic effects which in New York require only a minute; and the further statement of travelers, engaged in copying the antiquities of Yucatan, that they frequently have been obliged to abandon the use of the camera, and take to their sketch-books, have led to some investigations, similar to those at Kew, for determining the intensity of the chemically-active rays in the tropics. Prof. Thorpe experimented at Pará, situated nearly under the equator, in the northern province of the Brazils, and lying on a branch of the Amazon. Of the results, Prof. Roscoe remarks: "Owing to the rainy season having commenced when the experiments were made, the changes in the chemical intensity, as observed from hour to hour, and even from minute to minute, are very sudden and remarkable; this is well shown by the zigzag lines of Figs. 5 and 6; and these, compared with the dotted lines below, indicating the corresponding action on the same



FIGS. 5 AND 6.—VARIATION OF CHEMICAL RAYS IN THE TROPICS.

day at Kew, show the enormous variation in chemical intensity which occurs under a tropical sun in the rainy season. Regularly every afternoon, and frequently at other hours of the day, enormous thunder-clouds obscure the sky, and, discharging their contents in the form of deluging rain, reduce the chemical action nearly to zero. The storm quickly passes over, and the chemical intensity rapidly rises to its normal value. By comparing the curves for Pará and Kew on the same days, we obtain some idea of the energy of chemical action at the tropics, and it is at once evident that the alleged failure of the photographer cannot at any rate be ascribed to a diminution in the sun's chemical intensity, which, in the month of April, 1866, was nearly seven times as great at Pará as at Kew."

ON SOME OF THE RESULTS OF THE EXPEDITION OF H. M. S. CHALLENGER.

By Prof. THOMAS H. HUXLEY, F. R. S.

IN May, 1873, I drew attention, in the pages of this *Review*, to the important problems connected with the physics and natural history of the sea, to the solution of which there was every reason to hope the cruise of H. M. S. Challenger would furnish important contributions. The expectation then expressed has not been disappointed. Reports to the Admiralty, papers communicated to the Royal Society, and large collections which have already been sent home, have shown that the Challenger's staff have made admirable use of their great opportunities; and that, on the return of the expedition in 1874, their performance will be fully up to the level of their promise. Indeed, I am disposed to go so far as to say that, if nothing more came of the Challenger's expedition than has hitherto been yielded by her exploration of the nature of the sea-bottom at great depths, a full scientific equivalent of the trouble and expense of her equipment would have been obtained.

In order to justify this assertion, and yet, at the same time, not to claim more for Prof. Wyville Thomson and his colleagues than is their due, I must give a brief history of the observations which have preceded their exploration of this recondite field of research, and endeavor to make clear what was the state of knowledge in December, 1872, and what new facts have been added by the scientific staff of the Challenger. So far as I have been able to discover, the first successful attempt to bring up from great depths more of the sea-bottom than would adhere to a sounding-lead, was made by Sir John Ross, in the voyage to the arctic regions which he undertook in 1818. In the Appendix to the narrative of that voyage, there will be found an account of a very ingenious apparatus called "chlams"—a sort of double scoop—of his own contrivance, which Sir John Ross had made by the ship's armorer; and by which, being in Baffin's Bay, in 72° 30′ north, and 77° 15′ west, he succeeded in bringing up from 1,050 fathoms (or 6,300 feet), "several pounds" of a "fine green mud," which formed the bottom of the sea in this region. Captain (now Sir Edward) Sabine, who accompanied Sir John Ross on this cruise, says of this mud that it was "soft and greenish, and that the lead sunk several feet into it." A similar "fine green mud" was found to compose the sea-bottom in Davis Straits by Goodsir in 1845. Nothing is certainly known of the exact nature of the mud thus obtained, but we shall see that the mud of the bottom of the antarctic seas is described in curiously similar terms by Dr. Hooker, and there is no doubt as to the composition of this deposit.

In 1850 Captain Penny collected in Assistance Bay, in Kingston Bay, and in Melville Bay, which lie between 73° 45′ and 74° 40′ north, specimens of the residuum left by melted surface-ice, and of the sea-bottom in these localities. Dr. Dickie, of Aberdeen, sent these materials to Ehrenberg, who made out[1] that the residuum of the melted ice consisted for the most part of the silicious cases of diatomaceous plants, and of the silicious spicula of sponges; while, mixed with these, were a certain number of the equally silicious skeletons of those low animal organisms, which were termed *Polycistineæ* of Ehrenberg, but are now known as *Radiolaria*.

In 1856 a very remarkable addition to our knowledge of the nature of the sea-bottom in high northern latitudes was made by Prof. Bailey, of West Point. Lieutenant Brooke, of the United States Navy, who was employed in surveying the Sea of Kamtchatka, had succeeded in obtaining specimens of the sea-bottom from greater depths than any hitherto reached, namely, from 2,700 fathoms (16,200 feet) in 56° 46′ north, and 168° 18′ east; and from 1,700 fathoms (10,200 feet) in 60° 15′ north, and 170° 53′ east. On examining these microscopically, Prof. Bailey found, as Ehrenberg had done in the case of mud obtained on the opposite side of the arctic region, that the fine mud was made up of shells of *Diatomaceæ*, of spicula of sponges, and of *Radiolaria*, with a small admixture of mineral matters, but without a trace of any calcareous organisms.

Still more complete information has been obtained concerning the nature of the sea-bottom in the cold zone around the south pole. Between the years 1839 and 1843, Sir James Clark Ross executed his famous antarctic expedition, in the course of which he penetrated, at two widely-distant points of the antarctic zone, into the high latitudes of the shores of Victoria Land and of Graham's Land, and reached the parallel of 80° south. Sir James Ross was himself a naturalist of no mean acquirements, and Dr. Hooker, the present President of the Royal Society, accompanied him as naturalist to the expedition, so that the observations upon the fauna and flora of the antarctic regions made during this cruise were sure to have a peculiar value and importance, even had not the attention of the voyagers been particularly directed to the importance of noting the occurrence of the minutest forms of animal and vegetable life in the ocean.

Among the scientific instructions for the voyage drawn up by a committee of the Royal Society, however, there is a remarkable letter from Von Humboldt to Lord Minto, then First Lord of the Admiralty, in which, among other things, he dwells upon the significance of the researches into the microscopic composition of rocks, and the discovery of the great share which microscopic organisms take in the formation of the crust of the earth at the present day, made by Ehrenberg

[1] "Ueber neue Auschauungen des kleinsten nördlichen Polarlebens," *Monatsberichte der Königlichen Akademie*, Berlin, 1853.

in the years 1836–'39. Ehrenberg, in fact, had shown that the extensive beds of "rotten-stone" or "Tripoli" which occur in various parts of the world, and notably at Bilin in Bohemia, consisted of accumulations of the silicious cases and skeletons, *Diatomaceæ*, sponges, and *Radiolaria;* he had proved that similar deposits were being formed by *Diatomaceæ* in the pools of the Thiergarten, in Berlin and elsewhere, and had pointed out that, if it were commercially worth while, rotten-stone might be manufactured by a process of diatom-culture. Observations, conducted at Cuxhaenv in 1839, had revealed the existence, at the surface of the waters of the Baltic, of living diatoms and *Radiolaria* of the same species as those which, in a fossil state, constitute extensive rocks of Tertiary age at Caltanisetta, Zante, and Oran, on the shores of the Mediterranean.

Moreover, in the fresh-water rotten-stone beds of Bilin, Ehrenberg had traced out the metamorphosis, effected apparently by the action of percolating water, of the primitively loose and friable deposit of organized particles, in which the silex exists in the hydrated or soluble condition. The silex, in fact, undergoes solution and slow redeposition, until, in ultimate result, the excessively fine-grained sand, each particle of which is a skeleton, becomes converted into a dense opaline stone, with only here and there an indication of an organism.

From the consideration of these facts, Ehrenberg, as early as the year 1839, had arrived at the conclusion that rocks, altogether similar to those which constitute a large part of the crust of the earth, must be forming, at the present day, at the bottom of the sea; and he threw out the suggestion that even where no traces of organic structure is to be found in the older rocks, it may have been lost by metamorphosis.[1]

The results of the antarctic exploration, as stated by Dr. Hooker in the "Botany of the Antarctic Voyage," and in a paper which he read before the British Association in 1847, are of the greatest importance in connection with these views, and they are so clearly stated in the former work, which is somewhat inaccessible, that I make no apology for quoting them at length:

"The waters and the ice of the South Polar Ocean were alike found to abound with microscopic vegetables belonging to the order *Diatomaceæ*. Though much too small to be discernible by the naked eye, they occurred in such countless myriads as to stain the berg and the pack-ice wherever they were washed by the swell of the sea; and, when inclosed in the congealing surface of the water, they imparted to the brash and pancake-ice a pale ochreous color. In the open ocean, northward of the frozen zone, this order, though no doubt al-

[1] "Ueber die noch jetzt zahlreich lebenden Thierarten der Kreidebildung und den Organismus der Polythalamien," *Abhandlungen der Königlichen Akademie der Wissenschaften*, 1839. Berlin, 1841. I am afraid that this remarkable paper has been somewhat overlooked in the recent discussions of the relation of ancient rocks to modern deposits.

most universally present, generally eludes the search of the naturalist; except when its species are congregated among that mucous scum which is sometimes seen floating on the waves, and of whose real nature we are ignorant; or when the colored contents of the marine animals who feed on these algæ are examined. To the south, however, of the belt of ice which encircles the globe, between the parallels of 50° and 70° south, and in the waters comprised between that belt and the highest latitude ever attained by man, this vegetation is very conspicuous, from the contrast between its color and the white snow and ice in which it is embedded. Insomuch, that in the eightieth degree, all the surface-ice carried along by the currents, the sides of every berg, and the base of the great Victoria Barrier itself, within reach of the swell, were tinged brown, as if the polar waters were charged with oxide of iron.

"As the majority of these plants consist of very simple vegetable cells, inclosed in the indestructible silex (as other algæ are in carbonate of lime), it is obvious that the death and decomposition of such multitudes must form sedimentary deposits, proportionate in their extent to the length and exposure of the coast against which they are washed, in thickness to the power of such agents as the winds, currents, and sea, which sweep them more energetically to certain positions, and in purity, to the depth of the water and nature of the bottom. Hence we detected their remains along every ice-bound shore, in the depths of the adjacent ocean, between 80 and 400 fathoms. Off Victoria Barrier (a perpendicular wall of ice between 100 and 200 feet above the level of the sea) the bottom of the ocean was covered with a stratum of pure white or green mud, composed principally of the silicious shells of the *Diatomaceæ*. These, on being put into water, rendered it cloudy like milk, and took many hours to subside. In the very deep water off Victoria and Graham's Land, this mud was particularly pure and fine; but toward the shallow shores there existed a greater or less admixture of disintegrated rock and sand; so that the organic compounds of the bottom frequently bore but a small proportion to the inorganic. . . ."

"The universal existence of such an invisible vegetation as that of the Antarctic Ocean is a truly wonderful fact, and the more from its not being accompanied by plants of a high order. During the years we spent there, I had been accustomed to regard the phenomena of life as differing totally from what obtains throughout all other latitudes, for every thing living appeared to be of animal origin. The ocean swarmed with *Mollusca*, and particularly entomostratous *Crustacea*, small whales, and porpoises; the sea abounded with penguins and seals, and the air with birds; the animal kingdom was ever present, the larger creatures preying on the smaller, and these again on smaller still; all seemed carnivorous. The herviborous were not recognized, because feeding on a microscopic herbage, of whose true nature I had formed an erroneous impression. It is, therefore, with no little satisfaction that I now class the *Diatomaceæ* with plants, probably maintaining in the South Polar Ocean that balance between the vegetable and animal kingdoms which prevails over the surface of our globe. Nor is the sustenance and nutrition of the animal kingdom the only function these minute productions may perform; they may also be the purifiers of the vitiated atmosphere, and thus execute in the antarctic latitudes the office of our trees and grass-turf in the temperate regions, and the broad leaves of the palm, etc., in the tropics. . . ."

With respect to the distribution of the *Diatomaceæ*, Dr. Hooker remarks:

"There is probably no latitude, between that of Spitzbergen and Victoria Land, where some of the species of either country do not exist: Iceland, Britain, the Mediterranean Sea, North and South America, and the South-Sea Islands, all possess antarctic *Diatomaceæ*. The silicious coats of species only known living in the waters of the South Polar Ocean, have, during past ages, contributed to the formation of rocks; and thus they outlive several successive creations of organized beings. The phronolite stones of the Rhine, and the Tripoli stone, contain species identical with what are now contributing to form a sedimentary deposit (and, perhaps, at some future period, a bed of rock) extending in one continuous stratum for 400 measured miles. I allude to the shores of the Victoria Barrier, along whose coast the soundings examined were invariably charged with diatomaceous remains, constituting a bank which stretches 200 miles north from the base of Victoria Barrier, while the average depth of water above it is 300 fathoms, or 1,800 feet. Again, some of the antarctic species have been detected floating in the atmosphere which overhangs the wide ocean between Africa and America. The knowledge of this marvelous fact we owe to Mr. Darwin, who, when he was at sea off the Cape de Verd Islands, collected an impalpable powder which fell on Captain Fitzroy's ship. He transmitted this dust to Ehrenberg, who ascertained it to consist of the silicious coats, chiefly of American *Diatomaceæ*, which were being wafted through the upper region of the air, when some meteorological phenomena checked them in their course and deposited them on the ship and surface of the ocean.

"The existence of the remains of many species of this order (and among them some antarctic ones) in the volcanic ashes, pumice, and scoriæ of active and extinct volcanoes (those of the Mediterranean Sea and Ascension Island, for instance), is a fact bearing immediately upon the present subject. Mount Erebus, a volcano 12,400 feet high, of the first class in dimensions and energetic action, rises at once from the ocean in the seventy-eighth degree of south latitude, and abreast of the *Diatomaceæ* bank, which reposes in part on its base. Hence it may not appear preposterous to conclude that, as Vesuvius receives the waters of the Mediterranean, with its fish, to eject them by its crater, so the subterranean and subaqueous forces which maintain Mount Erebus in activity may occasionally receive organic matter from the bank, and disgorge it, together with those volcanic products, ashes and pumice.

"Along the shores of Graham's Land and the South Shetland Islands we have a parallel combination of igneous and aqueous action, accompanied with an equally copious supply of *Diatomaceæ*. In the Gulf of Erebus and Terror, fifteen degrees north of Victoria Land, and placed on the opposite side of the globe, the soundings were of a similar nature with those of the Victoria Land and Barrier, and the sea and ice as full of *Diatomaceæ*. This was not only proved by the deep-sea lead, but by the examination of bergs which, once stranded, had floated off and become reversed, exposing an accumulation of white friable mud frozen to their bases, which abounded with these vegetable remains."

The Challenger has explored the antarctic seas in a region intermediate between those examined by Sir James Ross's expedition; and the observations made by Dr. Wyville Thomson and his colleagues in every respect confirm those of Dr. Hooker:

"On the 11th of February, latitude 60° 52′ south, longitude 80° 20′ east, and March 3d, latitude 53° 55′ south, longitude 108° 35′ east, the sounding instrument came up filled with a very fine cream-colored paste, which scarcely effer-

vesced with acid, and dried into a very light, impalpable, white powder. This, when examined under the microscope, was found to consist almost entirely of the frustules of diatoms, some of them wonderfully perfect in all the details of their ornament, and many of them broken up. The species of diatoms entering into this deposit have not yet been worked up, but they appear to be referable chiefly to the genera *Fragillaria*, *Coscinodiscus*, *Chætoceros*, *Asteromphalus*, and *Dictyocha*, with fragments of the separated rods of a singular silicious organism, with which we were unacquainted, and which made up a large proportion of the finer matter of this deposit. Mixed with the diatoms there were a few small *Globigerinæ*, some of the tests and spicules of radiolarians, and some sand-particles; but these foreign bodies were in too small proportion to affect the formation as consisting practically of diatoms alone. On the 4th of February, in latitude 52° 29′ south, longitude 71° 36′ east, a little to the north of the Heard Islands, the tow-net, dragging a few fathoms below the surface, came up nearly filled with a pale-yellow gelatinous mass. This was found to consist entirely of diatoms of the same species as those found at the bottom. By far the most abundant was the little bundle of silicious rods, fastened together loosely at one end, separating from one another at the other end, and the whole bundle loosely twisted into a spindle. The rods are hollow, and contain the characteristic endochrome of the *Diatomaceæ*. Like the *Globigerina* ooze, then, which it succeeds to the southward in a band apparently of no great width, the materials of this silicious deposit are derived entirely from the surface and intermediate depths. It is somewhat singular that diatoms did not appear to be in such large numbers on the surface over the diatom-ooze as they were a little farther north. This may perhaps be accounted for by our not having struck their belt of depth with the tow-net; or it is possible that, when we found it on the 11th of February, the bottom deposit was really shifted a little to the south by the warm current, the excessively fine flocculent *débris* of the diatoms taking a certain time to sink. The belt of diatom-ooze is certainly a little farther to the southward in longitude 83° east, in the path of the reflux of the Agulhas current, than in longitude 108° east.

"All along the edge of the ice-pack—everywhere, in fact, to the south of the two stations—on the 11th of February, on our southward voyage, and on the 3d of March, on our return, we brought up fine sand and grayish mud, with small pebbles of quartz and feldspar, and small fragments of mica-slate, chlorite-slate, clay-slate, gneiss, and granite. This deposit, I have no doubt, was derived from the surface like the others, but in this case by the melting of icebergs and the precipitation of foreign matter contained in the ice.

"We never saw any trace of gravel or sand, or any material necessarily derived from land, on an iceberg. Several showed vertical or irregular fissures filled with discolored ice or snow; but, when looked at closely, the discoloration proved usually to be very slight, and the effect at a distance was usually due to the foreign material filling the fissure reflecting light less perfectly than the general surface of the berg. I conceive that the upper surface of one of these great tabular southern icebergs, including by far the greater part of its bulk, and culminating in the portion exposed above the surface of the sea, was formed by the piling up of successive layers of snow during the period, amounting perhaps to several centuries, during which the ice-cap was slowly forcing itself over the low land and out to sea over a long extent of gentle slope, until it reached a depth considerably above 200 fathoms, when the lower specific weight of the ice caused an upward strain which at length overcame the cohesion of the mass,

and portions were rent off and floated away. If this be the true history of the formation of these icebergs, the absence of all land *débris* in the portion exposed above the surface of the sea is readily understood. If any such exist, it must be confined to the lower part of the berg, to that part which has at one time or other moved on the floor of the ice-cap.

"The icebergs, when they are first dispersed, float in from 200 to 250 fathoms. When, therefore, they have been drifted to latitudes of 65° or 64° south, the bottom of the berg just reaches the layer at which the temperature of the water is distinctly rising, and it is rapidly melted, and the mud and the pebbles with which it is more or less charged are precipitated. That this precipitation takes place all over the area where the icebergs are breaking up, constantly, and to a considerable extent, is evident from the fact of the soundings being entirely composed of such deposits; for the diatoms, *Globigerinæ*, and radiolarians, are present on the surface in large numbers; and unless the deposit from the ice were abundant it would soon be covered and masked by a layer of the exuvia of surface organisms."

The observations which have been detailed leave no doubt that the antarctic sea-bottom, from a little to the south of the fiftieth parallel, as far as 80° south, is being covered by a fine deposit of silicious mud, more or less mixed, in some parts, with the ice-borne *débris* of polar lands and with the ejections of volcanoes. The silicious particles which constitute this mud are derived, in part, from the diatomaceous plants and radiolarian animals which throng the surface, and, in part, from the spicula of sponges which live at the bottom. The evidence respecting the corresponding arctic area is less complete, but it is sufficient to justify the conclusion that an essentially similar silicious cap is being formed around the northern pole.

There is no doubt that the constituent particles of this mud may agglomerate into a dense rock, such as that formed at Oran, on the shores of the Mediterranean, which is made up of similar materials. Moreover, in the case of fresh-water deposits of this kind, it is certain that the action of percolating water may convert the originally soft and friable, fine-grained sandstone into a dense semi-transparent opaline stone, the silicious organized skeletons being dissolved, and the silex redeposited in an amorphous state. Whether such a metamorphosis as this occurs in submarine deposits, as well as in those formed in fresh water, does not appear; but there seems no reason to doubt that it may. And hence it may not be hazardous to conclude that very ordinary metamorphic agencies may convert these polar caps into a form of quartzite.

In the great intermediate zone, occupying some 110° of latitude, which separates the circumpolar arctic and antarctic areas of silicious deposit, the diatoms and *Radiolaria* of the surface-water and the sponges of the bottom do not die out, and, so far as some forms are concerned, do not even appear to diminish in total number; though, on a rough estimate, it would appear that the proportion of *Radiola-*

ria to diatoms is much greater than in the colder seas. Nevertheless the composition of the deep-sea mud of this intermediate zone is entirely different from that of the circumpolar regions.

The first exact information respecting the nature of this mud at depths greater than 1,000 fathoms was given by Ehrenberg, in the account which he published in the "Monatsberichte" of the Berlin Academy for the year 1853, of the soundings obtained by Lieutenant Berryman, of the United States Navy, in the North Atlantic, between Newfoundland and the Azores.

Observations which confirm those of Ehrenberg in all essential respects have been made by Prof. Bailey, myself, Dr. Wallich, Dr. Carpenter, and Prof. Wyville Thomson, in their earlier cruises; and the continuation of the *Globigerina* ooze over the South Pacific has been proved by the recent work of the Challenger, by which it is also shown, for the first time, that, in passing from the equator to high southern latitudes, the number and variety of the *Foraminifera* diminish, and even the *Globigerinæ* become dwarfed. And this result, it will be observed, is in entire accordance with the fact already mentioned that, in the sea of Kamtchatka, the deep sea mud was found by Bailey to contain no calcareous organisms.

Thus, in the whole of the "intermediate zone," the silicious deposit which is being formed there, as elsewhere, by the accumulation of sponge-spicula, *Radiolaria*, and diatoms, is obscured and overpowered by the immensely greater amount of calcareous sediment, which arises from the aggregation of the skeletons of dead *Foraminifera*. The similarity of the deposit, thus composed of a large percentage of carbonate of lime, and a small percentage of silex, to chalk, regarded merely as a kind of rock, which was first pointed out by Ehrenberg,[1] is now admitted on all hands; nor can it be resonably doubted that ordinary metamorphic agencies are competent to convert the "modern chalk" into hard limestone, or even into crystalline marble.

Ehrenberg appears to have taken it for granted that the *Globi-*

[1] The following passages, in Ehrenberg's memoir on "The Organisms in the Chalk which are still living" (1839), are conclusive:

"7. The dawning period of the existing living organic creation, if such a period is distinguishable (which is doubtful), can only be supposed to have existed on the other side of, and below, the chalk formation; and thus, either the chalk, with its wide-spread and thick beds, must enter into the series of newer formations, or some of the accepted four great geological periods—the quaternary, tertiary, and secondary formations—contain organisms which still live. It is more probable, in the proportion of three to one, that the transition or primary period is not different, but that it is only more difficult to examine and understand, by reason of the gradual and prolonged chemical decomposition and metamorphosis of many of its organic constituents."

"10. By the mass-forming *Infusoria* and *Polythalamia*, secondary are not distinguishable from tertiary formations; and, from what has been said, it is possible that, at this very day, rock-masses are forming in the sea, and being raised by volcanic agencies, the constitution of which, on the whole, is altogether similar to that of the chalk. The chalk remains distinguishable by its organic remains as a formation, but not as a kind of rock."

gerinæ and other *Foraminifera* which are found in the deep-sea mud, live at the great depths in which their remains are found; and he supports this opinion by producing evidence that the soft parts of these organisms are preserved, and may be demonstrated by removing the calcareous matter with dilute acids. In 1857 the evidence for and against this conclusion appeared to me to be insufficient to warrant a positive conclusion one way or the other, and I expressed myself, in my report to the Admiralty on Captain Dayman's soundings, in the following terms:

"When we consider the immense area over which this deposit is spread, the depth at which its formation is going on, and its similarity to chalk, and still more to the marls of Caltanisetta, the question, 'Whence are these organisms derived?' becomes one of high scientific interest.

"Three answers have suggested themselves:

"In accordance with the prevalent view of the limitation of life to comparatively small depths, it is imagined either: 1. That these organisms have drifted into their present position from shallower waters; or 2. That they habitually live at the surface of the ocean, and only fall down into their present position.

"1. I conceive that the first supposition is negatived by the extremely marked zoological peculiarity of the deep-sea fauna.

"Had the *Globigerinæ* been drifted into their present position from shallow water, we should find a very large proportion of the characteristic inhabitants of shallow water mixed with them, and this would the more certainly be the case, as the large *Globigerinæ*, so abundant in the deep-sea soundings, are, in proportion to their size, more massive and solid than almost any other *Foraminifera*. But the fact is, that the proportion of other *Foraminifera* is exceedingly small, nor have I found as yet, in the deep-sea deposits, any such matters as fragments of molluscous shells, of *Echini*, etc., which abound in shallow waters, and are quite as likely to be drifted as the heavy *Globigerinæ*. Again, the relative proportions of young and fully-formed *Globigerinæ* seem inconsistent with the notion that they have traveled far. And it seems difficult to imagine why, had the deposit been accumulated in this way, *Coscinodisci* should so almost entirely represent the *Diatomaceæ*.

"2. The second hypothesis is far more feasible, and is strongly supported by the fact that many *Polycistineæ* (*Radiolaria*) and *Coscinodisci* are well known to live at the surface of the ocean. Mr. Macdonald, Assistant Surgeon of H. M. S. Herald, now in the Southwestern Pacific, has lately sent home some very valuable observations on living forms of this kind, met with in the stomachs of oceanic mollusks, and therefore certainly inhabitants of the superficial layer of the ocean. But it is a singular circumstance that only one of the forms figured by Mr. Macdonald is at all like a *Globigerina*, and there are some peculiarities about even this which make me greatly doubt its affinity with that genus. The form, indeed, is not unlike that of a *Globigerina*, but it is provided with long radiating processes, of which I have never seen any trace in *Globigerina*. Did they exist, they might explain what otherwise is a great objection to this view, viz., how is it conceivable that the heavy *Globigerina* should maintain itself at the surface of the water?

"If the organic bodies in the deep-sea soundings have neither been drifted, nor have fallen from above, there remains but one alternative—they must have lived and died as they are.

"Important objections, however, at once suggest themselves to this view. How can animal life be conceived to exist under such conditions of light, temperature, pressure, and aëration as must obtain at these vast depths?

"To this one can only reply that we know for a certainty that even very highly-organized animals do continue to live at a depth of 300 and 400 fathoms, inasmuch as they have been dredged up thence; and that the difference in the amount of light and heat at 400 and 2,000 fathoms is probably, so to speak, very far less than the difference in complexity of organization between these animals and the humbler *Protozoa* and *Protophyta* of the deep-sea soundings.

"I confess, though as yet far from regarding it proved that the *Globigerinæ* live at these depths, the balance of probabilities seems to me to incline in that direction. And there is one circumstance which weighs strongly in my mind. It may be taken as a law that any genus of animals that is found far back in time is capable of living under a great variety of circumstances as regards light, temperature, and pressure. Now, the genus *Globigerina* is abundantly represented in the Cretaceous epoch, and perhaps earlier.

"I abstain, however, at present from drawing any positive conclusions, preferring rather to await the result of more extended observations."[1]

Dr. Wallich, Prof. Wyville Thomson, and Dr. Carpenter, concluded that the *Globigerinæ* live at the bottom. Dr. Wallich writes in 1862: "By sinking very fine gauze-nets to considerable depths, I have repeatedly satisfied myself that *Globigerina* does not occur in the superficial strata of the ocean."[2] Moreover, having obtained certain living star-fish from a depth of 1,260 fathoms, and found their stomachs full of "fresh-looking *Globigerinæ*" and their *débris*, he adduces this fact in support of his belief that the *Globigerinæ* live at the bottom.

On the other hand, Müller, Häckel, Major Owen, Mr. Gwyn Jeffries, and other observers, found that *Globigerinæ*, with the allied genera *Orbulina* and *Pulvinulina*, sometimes occur abundantly at the surface of the sea, the shells of these pelagic forms being not unfrequently provided with the long spines noticed by Macdonald; and in 1865 and 1866 Major Owen more especially insisted on the importance of this fact. The recent work of the Challenger fully confirms Major Owen's statement. In the paper recently published in the proceedings of the Royal Society,[3] from which a quotation has already been made, Prof. Wyville Thomson says:

"I had formed and expressed a very strong opinion on the matter. It seemed to me that the evidence was conclusive that the *Foraminifera* which formed the *Globigerina* ooze lived on the bottom, and that the occurrence of individuals on the surface was accidental and exceptional; but, after going into the thing carefully, and considering the mass of evidence which has been accumulated by Mr. Murray, I now admit that I was in error; and I agree with him that it may be

[1] Appendix to "Report on Deep-Sea Soundings in the Atlantic Ocean," by Lieutenant-Commander Joseph Dayman, 1857.

[2] The "North Atlantic Sea-Bed," p. 137.

[3] "Preliminary Notes on the Nature of the Sea-Bottom procured by the Soundings of H. M. S. Challenger during her Cruise in the Southern Seas in the Early Part of the Year 1874."—(Proceedings of the Royal Society, November 26, 1874.)

taken as proved that all the materials of such deposits, with the exception, of course, of the remains of animals which we now know to live at the bottom of all depths, which occur in the deposit as foreign bodies, are derived from the surface.

"Mr. Murray has combined with a careful examination of the soundings a constant use of the tow-net, usually at the surface, but also at depths of from 10 to 100 fathoms, and he finds the closest relation to exist between the surface fauna of any particular locality and the deposit which is taking place at the bottom. In all seas, from the equator to the polar ice, the tow-net contains *Globigerinæ*. They are more abundant and of a larger size in warmer seas; several varieties, attaining a large size, and presenting marked varietal characters, are found in the intertropical area of the Atlantic. In the latitude of Kerguelen they are less numerous and smaller, while farther south they are still more dwarfed, and only one variety, the typical *Globigerina bulloides*, is represented. The living *Globigerinæ* from the tow-net are singularly different in appearance from the dead shells we find at the bottom. The shell is clear and transparent, and each of the pores which penetrate it is surrounded by a raised crest, the crest round adjacent pores coalescing into a roughly hexagonal network, so that the pores appear to lie at the bottom of an hexagonal pit. At each angle of this hexagon the crest gives off a delicate, flexible, calcareous spine, which is sometimes four or five times the diameter of the shell in length. The spines radiate symmetrically from the direction of the centre of each chamber of the shell, and the sheaves of long transparent needles crossing one another in different directions have a very beautiful effect. The smaller inner chambers of the shell are entirely filled with an orange-yellow granular sarcode; and the large terminal chamber usually contains only a small irregular mass, or two or three small masses run together, of the same yellow sarcode stuck against one side, the remainder of the chamber being empty. No definite arrangement and no approach to structure was observed in the sarcode, and no differentiation, with the exception of round bright-yellow oil-globules, very much like those found in some of the radiolarians which are scattered, apparently irregularly, in the sarcode. We never have been able to detect, in any of the large number of *Globigerinæ* which we have examined, the least trace of pseudopodia, or any extension, in any form, of the sarcode beyond the shell. . . .

"In specimens taken with the tow-net the spines are very usually absent; but that is probably on account of their extreme tenuity; they are broken off by the slightest touch. In fresh examples from the surface, the dots indicating the origin of the lost spines may almost always be made out with a high power. There are never spines on the *Globigerinæ* from the bottom, even in the shallowest water."

There can now be no doubt, therefore, that the *Globigerinæ* live at the top of the sea; but the question may still be raised whether they do not also live at the bottom. In favor of this view, it has been urged that the shells of the *Globigerinæ* of the surface never possess such thick walls as those which are found at the bottom, but I confess that I doubt the accuracy of this statement. Again, the occurrence of minute *Globigerinæ* in all stages of development, at the greatest depths, is brought forward as evidence that they live *in situ*. But, considering the extent to which the surface-organisms are devoured, without discrimination of young and old, by *Salpæ* and the like, it is not wonderful that the shells of all ages should be among the *rejecta-*

menta. Nor can the presence of the soft parts of the body in the shells which form the *Globigerina* ooze, and the fact, if it be one, that animals living at the bottom use them as food, be considered as conclusive evidence that the *Globigerinæ* live at the bottom. Such as die at the surface, and even many of those which are swallowed up by other animals, may retain much of their protoplasmic matter when they reach the depths at which the temperature sinks to 34° or 32° Fahr., where decomposition must become exceedingly slow.

Another consideration appears to me to be in favor of the view that the *Globigerinæ* and their allies are essentially surface-animals. This is the fact brought out by the Challenger's work, that they have a southern limit of distribution, which can hardly depend upon any thing but the temperature of the surface-water. And it is to be remarked that this southern limit occurs at a lower latitude in the antarctic seas than it does in the North Atlantic. According to Dr. Wallich ("The North-Atlantic Sea-Bed," p. 157) *Globigerina* is the prevailing form in the deposits between the Faroe Islands and Iceland, and between Iceland and East Greenland—or, in other words, in a region of the sea-bottom which lies altogether north of the parallel of 60° north; while in the southern seas the *Globigerinæ* become dwarfed and almost disappear between 50° and 55° south. On the other hand, in the sea of Kamtchatka, the *Globigerinæ* have vanished in 56° north, so that the persistence of the *Globigerina* ooze in high latitudes, in the North Atlantic, would seem to depend on the northward curve of the isothermals peculiar to this region; and it is difficult to understand how the formation of *Globigerina* ooze can be affected by this climatal peculiarity unless it be effected by surface animals.

Whatever may be the mode of life of the *Foraminifera*, to which the calcareous element of the deep-sea "chalk" owes its existence, the fact that it is the chief and most widely-spread material of the sea-bottom in the intermediate zone, throughout both the Atlantic and Pacific Oceans, and the Indian Ocean, at depths from a few hundred to over 2,000 fathoms, is established. But it is not the only extensive deposit which is now taking place. In 1853 Count Pourtalès, an officer of the United States Coast Survey, which has done so much for scientific hydrography, observed that the mud forming the sea-bottom at depths of 150 fathoms, in 31° 32′ north, and 79° 35′ west, off the coast of Florida, was "a mixture, in about equal proportions, of *Globigerinæ* and black sand, probably green sand, as it makes a green mark when crushed on paper." Prof. Bailey, examining these grains microscopically, found that they were casts of the interior cavities of *Foraminifera*, consisting of a mineral known as *Glauconite*, which is a silicate of iron and alumina. In these casts the minutest cavities and finest tubes in the *Foraminifera* were sometimes reproduced in solid counterparts of the glassy mineral, while the calcareous original had been entirely dissolved away.

Contemporaneously with these observations, the indefatigable Ehrenberg had discovered that the "greensands" of the geologist were largely made up of casts of a similar character, and proved the existence of *Foraminifera* at a very ancient geological epoch, by discovering such casts in a greensand of Lower Silurian age, which occurs near St. Petersburg.

Subsequently Messrs. Parker and Jones discovered similar casts in process of formation, the original shell not having disappeared, in specimens of the sea-bottom of the Australian seas, brought home by the late Prof. Jukes. And the Challenger has observed a deposit of a similar character in the course of the Agulhas current, near the Cape of Good Hope, and in some other localities not yet defined.

It would appear that this infiltration of *Foraminifera* shells with *Glauconite* does not take place at great depths, but rather in what may be termed a sublittoral region, ranging from 100 to 300 fathoms. It cannot be ascribed to any local cause, for it takes place, not only over large areas in the Gulf of Mexico and the coast of Florida, but in the South Atlantic and in the Pacific. But what are the conditions which determine its occurrence, and whence the silex, the iron, and the alumina (with perhaps potash and some other ingredients in small quantity) of which the *Glauconite* is composed, proceed, are points on which no light has yet been thrown. For the present we must be content with the fact that, in certain areas of the "intermediate zone," greensand is replacing and representing the primitive calcareo-silicious ooze.

The investigation of the deposits which are now being formed in the basin of the Mediterranean by the late Prof. Edward Forbes, by Prof. Williamson, and more recently by Dr. Carpenter, and a comparison of the results thus obtained with what is known of the surface fauna, have brought to light the remarkable fact that, while the surface and the shallows abound with *Foraminifera* and other calcareous-shelled organisms, the indications of life become scanty at depths beyond 500 or 600 fathoms, while almost all traces of it disappear at greater depths, and at 1,000 to 2,000 fathoms the bottom is covered with a fine clay.

Dr. Carpenter has discussed the significance of this remarkable fact, and he is disposed to attribute the absence of life at great depths partly to the absence of any circulation of the water of the Mediterranean at such depths, and partly to the exhaustion of the oxygen of the water by the organic matter contained in the fine clay, which he conceives to be formed by the finest particles of the mud brought down by the rivers which flow into the Mediterranean.

However this may be, the explanation thus offered of the presence of the fine mud, and of the absence of organisms which ordinarily live at the bottom, does not account for the absence of the skeletons

of the organisms which undoubtedly abound at the surface of the Mediterranean; and it would seem to have no application to the remarkable fact discovered by the Challenger, that in the open Atlantic and Pacific Oceans, in the midst of the great intermediate zone, and thousands of miles away from the embouchure of any river, the sea-bottom, at depths approaching to and beyond 3,000 fathoms, no longer consists of *Globigerina* ooze, but an excessively fine red clay.

Prof. Thomson gives the following account of this capital discovery:

"According to our present experience, the deposit of *Globigerina* ooze is limited to water of a certain depth, the extreme limit of the pure characteristic formation being placed at a depth of somewhere about 2,250 fathoms. Crossing from these shallower regions occupied by the ooze into deeper surroundings, we find universally that the calcareous formation gradually passes into, and is finally replaced by, an extremely fine pure clay, which occupies, speaking generally, all depths below 2,500 fathoms, and consists almost entirely of a silicate of the red oxide of iron and alumina. The transition is very slow, and extends over several hundred fathoms of increasing depth; the shells gradually lose their sharpness of outline, and assume a kind of 'rotten' look and a brownish color, and become more and more mixed with a fine amorphous red-brown powder, which increases steadily in proportion, until the lime has almost entirely disappeared. The brown matter is in the finest possible state of subdivision; so fine that, when, after sifting it to separate any organisms it might contain, we put it into jars to settle, it remained for days in suspension, giving the water very much the appearance and color of chocolate.

"In indicating the nature of the bottom on the charts, we came, from experience and without any theoretical considerations, to use three terms for soundings in deep water. Two of these, *Globigerina* ooze and red clay, were very definite, and indicated strongly-marked formations, with apparently but few characters in common; but we frequently got soundings which we could not exactly call '*Globigerina* ooze' or 'red clay,' and, before we were fully aware of the nature of these, we were in the habit of indicating them as 'gray ooze' (gr. oz.). We now recognize the 'gray ooze' as an intermediate stage between the *Globigerina* ooze and the red clay; we find that on one side, as it were, of an ideal line, the red clay contains more and more of the material of the calcareous ooze, while on the other the ooze is mixed with an increasing proportion of 'red clay.'

"Although we have met with the same phenomenon so frequently that we were at length able to predict the nature of the bottom from the depth of the surroundings with absolute certainty for the Atlantic and the Southern Sea, we had, perhaps, the best opportunity of observing it in our first section across the Atlantic, between Teneriffe and St. Thomas. The first four stations on this section, at depths from 1,525 to 2,220 fathoms, show *Globigerina* ooze. From the last of these, which is about 300 miles from Teneriffe, the depth gradually increases to 2,740 fathoms at 500, and 2,950 fathoms at 750 miles from Teneriffe. The bottom in these two soundings might have been called 'gray ooze,' for, although its nature has altered entirely from the *Globigerina* ooze, the red clay into which it is rapidly passing still contains a considerable admixture of carbonate of lime.

"The depth goes on increasing to a distance of 1,150 miles from Teneriffe,

when it reaches 3,150 fathoms; there the clay is pure and smooth, and contains scarcely a trace of lime. From this great depth the bottom gradually rises, and, with decreasing depth, the gray color and the calcareous composition of the ooze return. Three soundings, in 2,050, 1,900, and 1,950 fathoms on the 'Dolphin rise,' gave highly-characteristic examples of the *Globigerina* formation. Passing from the middle plateau of the Atlantic into the western trough, with depths a little over 3,000 fathoms, the red clay returned in all its purity; and our last sounding, in 1,420 fathoms, before reaching Sombrero, restored the *Globigerina* ooze with its peculiar associated fauna.

"This section shows also the wide extension and the vast geological importance of the red-clay formation. The total distance from Teneriffe to Sombrero is about 2,700 miles. Proceeding from east to west we have—

About 80 miles of volcanic mud and sand,
" 350 " *Globigerina* ooze,
" 1,050 " red clay,
" 330 " *Globigerina* ooze,
" 850 " red clay,
" 40 " *Globigerina* ooze;

giving a total of 1,900 miles of red clay to 720 miles of *Globigerina* ooze.

"The nature and origin of this vast deposit of clay is a question of the very greatest interest; and although I think there can be no doubt that it is in the main solved, yet some matters of detail are still involved in difficulty. My first impression was that it might be the most minutely-divided material, the ultimate sediment produced by the disintegration of the land, by rivers and by the action of the sea on exposed coasts, and held in suspension and distributed by ocean-currents, and only making itself manifest in places unoccupied by the *Globigerina* ooze. Several circumstances seemed, however, to negative this mode of origin. The formation seemed too uniform; wherever we met with it, it had the same character, and it only varied in composition in containing less or more carbonate of lime.

"Again, we were gradually becoming more and more convinced that all the important elements of the *Globigerina* ooze lived on the surface, and it seemed evident that, so long as the condition on the surface remained the same, no alteration of contour at the bottom could possibly prevent its accumulation; and the surface conditions in the mid-Atlantic were very uniform, a moderate current of a very equal temperature passing continuously over elevations and depressions, and everywhere yielding to the tow-net the ooze-forming *Foraminifera* in the same proportion. The mid-Atlantic swarms with pelagic *Mollusca*, and, in moderate depths, the shells of these are constantly mixed with the *Globigerina* ooze, sometimes in number sufficient to make up a considerable portion of its bulk. It is clear that these shells must fall in equal numbers upon the red-clay, but scarcely a trace of one of them is ever brought up by the dredge on the red-clay area. It might be possible to explain the absence of shell-secreting animals living on the bottom, on the supposition that the nature of the deposit was injurious to them; but then the idea of a current sufficiently strong to sweep them away is negatived by the extreme fineness of the sediment which is being laid down; the absence of surface-shells appears to be intelligible only on the supposition that they are in some way removed.

"We conclude, therefore, that the 'red clay' is not an additional substance introduced from without, and occupying certain depressed regions on account of some law regulating its deposition, but that it is produced by the removal, by

some means or other, over these areas, of the carbonate of lime, which forms probably about 98 per cent. of the material of the *Globigerina* ooze. We can trace, indeed, every successive stage in the removal of the carbonate of lime in descending the slope of the ridge or plateau where the *Globigerina* ooze is forming, to the region of the clay. We find, first, that the shells of pteropods and other surface *Mollusca*, which are constantly falling on the bottom, are absent, or, if a few remain, they are brittle and yellow, and evidently decaying rapidly. These shells of *Mollusca* decompose more easily and disappear sooner than the smaller, and apparently more delicate, shells of rhizopods. The smaller *Foraminifera* now give way, and are found in lessening proportion to the larger; the coccoliths first lose their thin outer border and then disappear; and the clubs of the rhabdoliths get worn out of shape, and are last seen, under a high power, as infinitely minute cylinders scattered over the field. The larger *Foraminifera* are attacked, and instead of being vividly white and delicately sculptured, they become brown and worn, and finally they break up, each according to its fashion; the chamber-walls of *Globigerina* fall into wedge-shaped pieces, which quickly disappear, and a thick rough crust breaks away from the surface of *Orbulina*, leaving a thin inner sphere, at first beautifully transparent, but soon becoming opaque and crumbling away.

"In the mean time the proportion of the amorphous 'red clay' to the calcareous elements of all kinds increases, until the latter disappear, with the exception of a few scattered shells of the larger *Foraminifera*, which are still found even in the most characteristic samples of the 'red clay.'

"There seems to be no room left for doubt that the red clay is essentially the insoluble residue, the *ash*, as it were, of the calcareous organisms which form the *Globigerina* ooze, after the calcareous matter has been by some means removed. An ordinary mixture of calcareous *Foraminifera* with the shells of pteropods, forming a fair sample of *Globigerina* ooze from near St. Thomas, was carefully washed, and subjected by Mr. Buchanan to the action of weak acid; and he found that there remained, after the carbonate of lime had been removed, about one per cent. of a reddish mud, consisting of silica, alumina, and the red oxide of iron. This experiment has been frequently repeated with different samples of *Globigerina* ooze, and always with the result that a small proportion of a red sediment remains, which possesses all the characters of the red clay . . . .

"It seems evident from the observations here recorded, that *clay*, which we have hitherto looked upon as essentially the product of the disintegration of older rocks, may be, under certain circumstances, an organic formation like chalk; that, as a matter of fact, an area on the surface of the globe, which we have shown to be of vast extent, although we are still far from having ascertained its limits, is being covered by such a deposit at the present day.

"It is impossible to avoid associating such a formation with the fine, smooth, homogeneous clays and schists, poor in fossils, but showing worm-tubes and tracks, and bunches of branching things, such as Oldhamia, silicious sponges, and thin-shelled peculiar shrimps. Such formations, more or less metamorphosed, are very familiar, especially to the student of palæozoic geology, and they often attain a vast thickness. One is inclined, from the great resemblance between them in composition and in the general character of the included fauna, to suspect that these may be organic formations, like the modern red clay of the Atlantic and Southern Sea, accumulations of the insoluble ashes of shelled creatures.

"The dredging in the red clay on the 13th of March was unusually rich.

The bag contained examples, those with calcareous shells rather stunted, of most of the characteristic groups of the Southern Sea, including *Umbellularia*, *Euplectella*, *Pterocrinus*, *Brisinga*, *Ophioglypha*, *Pourtalesia*, and one or two *Mollusca*. This is, however, very rarely the case. Generally the red clay is barren, or contains only a very small number of forms."

It must be admitted that it is very difficult at present to frame any satisfactory explanation of the mode of origin of this singular deposit of red clay.

I cannot say that the theory put forward tentatively, and with much reservation by Prof. Thomson, that the calcareous matter is dissolved out by the relatively fresh water of the deep currents from the antarctic regions, appears satisfactory to me. Nor do I see my way to the acceptance of the suggestion of Dr. Carpenter, that the red clay is the result of the decomposition of previously-formed greensand. At present there is no evidence that greensand casts are ever formed at great depths; nor has it been proved that *Glauconite* is decomposable by the agency of water and carbonic acid.

I think it probable that we shall have to wait some time for a sufficient explanation of the origin of the abyssal red clay, no less than for that of the sublittoral greensand in the intermediate zone. But the importance of the establishment of the fact that these various deposits are being formed in the ocean, at the present day, remains the same, whether its *rationale* be understood or not.

For suppose the globe to be evenly covered with sea, to a depth say of a thousand fathoms—then, whatever might be the mineral matter composing the sea-bottom, little or no deposit would be formed upon it, the abrading and denuding action of water, at such a depth, being exceedingly slight. Next, imagine sponges, *Radiolaria*, *Foraminifera*, and diatomaceous plants, such as those which now exist in the deep sea, to be introduced: they would be distributed according to the same laws as at present, the sponges (and possibly some of the *Foraminifera*) covering the bottom, while other *Foraminifera*, with the *Radiolaria* and *Diatomaceæ*, would increase and multiply in the surface-waters. In accordance with the existing state of things, the *Radiolaria* and diatoms would have a universal distribution, the latter gathering most thickly in the polar regions, while the *Foraminifera* would be largely, if not exclusively, confined to the intermediate zone; and, as a consequence of this distribution, a bed of "chalk" would begin to form in the intermediate zone, while caps of silicious rock would accumulate on the circumpolar regions.

Suppose, further, that a part of the intermediate area were raised to within 200 or 300 fathoms of the surface—for any thing that we know to the contrary, the change of level might determine the substitution of greensand for the "chalk;" while, on the other hand, if part of the same area were depressed to 3,000 fathoms, that change might determine the substitution of a different silicate of alumina

and iron—namely, clay—for the "chalk" that would otherwise be formed.

If the Challenger hypothesis, that the red clay is the residue left by dissolved *Foraminiferous* skeletons, is correct, then all these deposits alike would be directly, or indirectly, the product of living organisms. But just as a silicious deposit may be metamorphosed into opal or quartzite, and chalk into marble, so known metamorphic agencies may metamorphose clay into schist, clay-slate, slate, gneiss, or even granite. And thus, by the agency of the lowest and simplest of organisms, our imaginary globe might be covered with strata, of all the chief kinds of rock of which the known crust of the earth is composed, of indefinite thickness and extent.

The bearing of the conclusions which are now either established, or highly probable, respecting the origin of silicious, calcareous, and clayey rocks, and their metamorphic derivatives, upon the archæology of the earth, the elucidation of which is the ultimate object of the geologist, is of no small importance.

A hundred years ago the singular insight of Linnæus enabled him to say that "fossils are not the children but the parents of rocks,"[1] and the whole effect of the discoveries made since his time has been to compile a larger and larger commentary upon this text. It is, at present, a perfectly tenable hypothesis that all silicious and calcareous rocks are either directly, or indirectly, derived from material which has, at one time or other, formed part of the organized framework of living organisms. Whether the same generalization may be extended to aluminous rocks, depends upon the conclusion to be drawn from the facts respecting the red-clay areas brought to light by the Challenger. If we accept the view taken by Mr. Wyville Thomson and his colleagues—that the red clay is the residuum left after the calcareous matter of the *Globigerinæ* ooze has been dissolved away—then clay is as much a product of life as limestone, and all known derivatives of clay may have formed part of animal bodies.

So long as the *Globigerinæ*, actually collected at the surface, have not been demonstrated to contain the elements of clay, the Challenger hypothesis, as I may term it, must be accepted with reserve and provisionally, but, at present, I cannot but think that it is more probable than any other suggestion which has been made.

Accepting it provisionally, we arrive at the remarkable result that all the chief known constituents of the crust of the earth may have

[1] "Petrificata montium calcariorum non filii sed parentes sunt, cum omnis calx oriatur ab animalibus." "Systema Naturæ," Ed. xii., t. iii., p. 154. It must be recollected that Linnæus included silex, as well as limestone, under the name of "calx," and that he would probably have arranged diatoms among animals, as part of "chaos." Ehrenberg quotes another even more pithy passage, which I have not been able to find in any edition of the "Systema" accessible to me: "Sic lapides ab animalibus, nec vice versa. Sic rupes saxei non primævi, sed temporis filiæ."

formed part of living bodies; that they may be the "ash" of protoplasm; that the "*rupes saxei*" are not only "*temporis*," but "*vitæ filiæ;*" and, consequently, that the time during which life has been active on the globe may be indefinitely greater than the period the commencement of which is marked by the oldest known rocks, whether fossiliferous or unfossiliferous.

And thus we are led to see where the solution of a great problem and apparent paradox of geology may lie. Satisfactory evidence now exists that some animals in the existing world have been derived by process of gradual modification from preëxisting forms. It is undeniable, for example, that the evidence in favor of the derivation of the horse from the later tertiary *Hipparion*, and that of the *Hipparion* from *Anchitherium*, is as complete and cogent as such evidence can reasonably be expected to be; and, the further investigations into the history of the tertiary mammalia are pushed, the greater is the accumulation of evidence having the same tendency. So far from paleontology lending no support to the doctrine of evolution—as one sees constantly asserted—that doctrine, if it had no other support, would have been irresistibly forced upon us by the paleontological discoveries of the last twenty years.

If, however, the diverse forms of life which now exist have been produced by the modification of previously-existing less divergent forms, the recent and extinct species, taken as a whole, must fall into series which must converge as we go back in time. Hence, if the period represented by the rocks is greater than, or coextensive with, that during which life has existed, we ought, somewhere among the ancient formations, to arrive at the point to which all these series converge, or from which, in other words, they have diverged—the primitive undifferentiated protoplasmic living things, whence the two great series of plants and animals have taken their departure.

But, as a matter of fact, the amount of convergence of series, in relation to the time occupied by the deposition of geological formations, is extraordinarily small. Of all animals the higher *Vertebrata* are the most complex; and among these the carnivores and hoofed animals (*Ungulata*) are highly differentiated. Nevertheless, although the different lines of modification of the *Carnivora* and those of the *Ungulata*, respectively, approach one another, and, although each group is represented by less differentiated forms in the older tertiary rocks than at the present day, the oldest tertiary rocks do not bring us near the primitive form of either. If, in the same way, the convergence of the varied forms of reptiles is measured against the time during which their remains are preserved—which is represented by the whole of the tertiary and mesozoic formations—the amount of that convergence is far smaller than that of the lines of mammals, between the present time and the beginning of the tertiary epoch. And it is a broad fact that, the lower we go in the scale of organization,

the fewer signs are there of convergence toward the primitive form whence all must have diverged, if evolution be a fact. Nevertheless, that it is a fact in some cases, is proved, and I, for one, have not the courage to suppose that the mode in which some species have taken their origin is different from that in which the rest have originated.

What, then, has become of all the marine animals which, on the hypothesis of evolution, must have existed in myriads in those seas, wherein the many thousand feet of Cambrian and Laurentian rocks, now devoid, or almost devoid, of any trace of life, were deposited?

Sir Charles Lyell long ago suggested that the azoic character of these ancient formations might be due to the fact that they had undergone extensive metamorphosis; and readers of the "Principles of Geology" will be familiar with the ingenious manner in which he contrasts the theory of the Gnome, who is acquainted only with the interior of the earth, with those of ordinary philosophers, who know only its exterior.

The metamorphism contemplated by the great modern champion of rational geology is, mainly, that brought about by the exposure of rocks to subterranean heat, and, where no such heat could be shown to have operated, his opponents assumed that no metamorphosis could have taken place. But the formation of greensand, and still more that of the "red clay" (if the Challenger hypothesis be correct) affords an insight into a new kind of metamorphosis—not igneous, but aqueous—by which the primitive nature of a deposit may be masked as completely as it can be by the agency of heat. And, as Wyville Thomson suggests, in the passage I have quoted above (p. 17), it further enables us to assign a new cause for the occurrence, so puzzling hitherto, of thousands of feet of unfossiliferous fine-grained schists and slates, in the midst of formations deposited in seas which certainly abounded in life. If the great deposit of "red clay" now forming in the eastern valley of the Atlantic were metamorphosed into slate and then upheaved, it would constitute an "azoic" rock of enormous extent. And yet that rock is now forming in the midst of a sea which swarms with living beings, the great majority of which are provided with calcareous or silicious shells and skeletons, and therefore are such as, up to this time, we should have termed eminently preservable.

Thus the discoveries made by the Challenger expedition, like all recent advances in our knowledge of the phenomena of biology, or of the changes now being effected in the structure of the surface of the earth, are in accordance with, and lend strong support to, that doctrine of Uniformitarianism, which, fifty years ago, was held only by a small minority of English geologists—Lyell, Scrope, and De la Beche—but now, thanks to the long-continued labors of the first two, and mainly to those of Sir Charles Lyell, has gradually passed from the position of a heresy to that of catholic doctrine.

Applied within the limits of the time registered by the known fraction of the crust of the earth, I believe that Uniformitarianism is unassailable. The evidence that, in the enormous lapse of time between the deposition of the lowest Laurentian strata and the present day, the forces which have modified the surface of the crust of the earth were different in kind, or greater in the intensity of their action, than those which are now occupied in the same work, has yet to be produced. Such evidence as we possess all tends in the contrary direction, and is in favor of the same slow and gradual changes occurring then as now.

But this conclusion in no wise conflicts with the deductions of the physicist from his no less clear and certain data. It may be certain that this globe has cooled down from a condition in which life could not have existed; it may be certain that, in so cooling, its contracting crust must have undergone sudden convulsions, which were to our earthquakes as an earthquake is to the vibration caused by the periodical eruption of a geyser; but in that case the earth must, like other respectable parents, have sowed her wild-oats, and got through her turbulent youth, before we, her children, have any knowledge of her.

So far as the evidence afforded by the superficial crust of the earth goes, the modern geologist can, *ex animo*, repeat the saying of Hutton, "We find no vestige of a beginning—no prospect of an end." However, he will add, with Hutton, "But in thus tracing back the natural operations which have succeeded each other, and mark to us the course of time past, we come to a period in which we cannot see any further." And if he seek to peer into the darkness of this period, he will welcome the light proffered by physics and mathematics.—*Contemporary Review.*

EVOLUTION AND THE AFTER-LIFE.

By R. OSGOOD MASON, A. M., M. D.

FEW persons are able to escape some form of belief in the existence of a soul. Whatever view we may take of its origin, gradations, or development, whether the infinite soul, the human, the animal, and the "soul of things," are each only manifestations in different degrees of the same great principle, or each enlargement and refinement in the ascending series is to be considered a development, or whether nothing is to be dignified as soul except that which is manifested through human forms—whatever views we may have regarding its limitations and destiny—we cannot escape the conviction that there is, in man at least, a distinct entity, a combination of faculties, a blending of sensation, will, and wisdom, which we call soul. Its powers, its modes of action, and its destiny, have been subjects of

thought for the thoughtful of all times. Gradually these thoughts have taken form, and a science of psychology has grown up, engaging in its investigations the efforts of the ablest minds.

It may not be reasonable to suppose that any being, unless it be the Infinite, should perfectly comprehend itself. How far man is from being able to claim such knowledge may be inferred when we consider that, although he has been upon the earth so many thousand years, it is less than three centuries since he began to understand even his physical organization, or comprehend such simple facts in his own physiology as the process of digestion and the circulation of the blood. It is only within the present century that the functions of the nervous system began to be understood, and only within the last few years that its relations to mental activity have been intelligently studied. With so many points in regard to the functions of the material body only recently understood, and even now but imperfectly known, is it strange that our psychical relations should be even less perfectly comprehended?

A recent writer[1] has pointed out the fact that each epoch of intellectual activity and enlargement, as marked by the discovery of new truths in Nature, has been accompanied or directly followed by better modes of investigation and more scientific views in psychology; and not only so, but the methods employed and the results obtained in psychology have had direct relation to the methods and results in physical science. As mathematics and the laws of motion gave us Descartes and Hobbes, scientific medicine or the "science of observation" Locke, the vibratory theory Hartley, and chemistry the elder Mill, so geology and the doctrine of evolution have been potent in influencing the methods and results obtained in psychology by Bain and Herbert Spencer. And as each advance in psychology has had reference to the methods in physical science which have preceded it, so do we find that the doctrine of evolution, which in its general aspect at least has given direction to the scientific thought of the present generation, has also been the doctrine which has thrown most light upon the constitution and action of mind.

It is not the object of this paper to discuss the doctrine of evolution, but simply in the light of that doctrine, as generally understood, to present such facts as science has prepared for us relative to the development of mind, and its manifesting organs in the gradually-ascending series of animal forms.

The organ of all psychical manifestation is the nervous system, and the material of which it is composed is substantially the same, whether in animals of a high or a low organization. It is of two kinds, the *gray matter*, usually found in nodules or masses of greater or less bulk, called *ganglia*, and the *white matter*, usually found in

[1] "The Development of Psychology," *Westminster Review*, and POPULAR SCIENCE MONTHLY, July and August, 1874.

continuous lines, and called *nerve-trunks*, or simply *nerves*. The ganglia are the *centres of power*. The trunks are the *lines of communication* between the ganglia and the different parts of the organism.

Without descending into the debatable ground between the vegetable and animal world (for, strange to say, the boundary-line between two modes of life apparently so different has never yet been established), let us examine an organism as lowly as any possessing a distinct and single nervous system—an ascidian mollusk—which simply means a bag-shaped, soft-bodied animal. It has no head, nor any

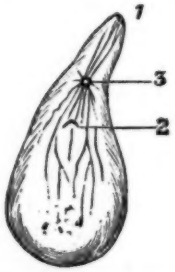


FIG. 1.—NERVOUS SYSTEM OF ASCIDIAN: 1. Mouth; 2. Vent; 3. Ganglion.

organs of sight, hearing, or smell. It consists of a sac, from the lower portion of which proceeds a stomach or digestive tube; these are covered with a muscular envelope, and the whole is inclosed in another envelope or membranous sac called a mantle. These coverings are pierced by two openings—a mouth for admitting water and the nutrient particles which it happens to contain into the inner sac or common reservoir, which also serves as a respiratory organ—and a vent, communicating directly with this sac, and also with the more circuitous digestive tube. A constant stream of water passes through the mouth into this common or respiratory sac, where, after having served its purpose of supplying oxygen to the system, a part is ejected directly through the vent, and the remainder, together with the nutrient particles, passes into the digestive tube, and thus finds its exit.

The nervous system, which is the part most important to our present purpose, is of the most simple kind; it consists of a single ganglion, situated between the two orifices of the body, with each of which it has lines of nerve-communication, and also with the various envelopes which mainly constitute the animal.

All the creature's movements must be carried on by means of this simple nervous arrangement; and, as it is fixed to one spot during its whole life, they must necessarily be of a very limited character; it has, in fact, but one movement—it contracts when touched.[1] Suppose, for instance, some offending substance to have found its way into the common sac, the *irritation* caused by it is transferred along the

[1] For many of the facts and illustrations here stated, see "Mental Physiology," by Dr. Carpenter, chapter ii.

communicating nerves *to* the ganglion; there a "motor impulse" is generated, which again is transferred along the communicating lines *from* the ganglion to the muscular envelope, causing it to contract and eject the water which it contained, together with the offending substance. This is all the action the creature is capable of, and this it repeats whenever and wherever an irritation is applied. It is the simplest action, so far as we know, requiring a nervous system for its accomplishment, and has received the name of *reflex action*.

Without following each shade of improvement in the nervous organization of the mollusks, or soft-bodied animals, it may suffice to say that the same general arrangement holds throughout all the lower members of the series, new ganglia being added to meet the needs of a more complex organization until, in the highest members, as, for instance, in snails and the cuttle-fish, important changes are found to have occurred. Instead of the headless and irregular masses which have constituted the bodies up to this point, we now find an animal comparatively symmetrical in form, with a distinct head, and imperfectly-developed organs of special sense. Here, then, occurs the division between the two great classes of animals known as *cephalous* and *acephalous;* all the lower species of mollusks, the ascidians, mussels, oysters, and the like, belong to the acephalous or headless class, while with the highest species, snails, the nautilus, and the cuttle-fish, commences the other great class known as cephalous animals, or those having distinct heads.

The advance in the nervous system is correspondingly great; instead of the irregularly-situated ganglia hitherto met with, we find them arranged in pairs, to serve the purposes of the more symmetrical body; but a still more marked and important advance is found in the fact that each organ of special sense (sight, hearing, etc.) is furnished with a separate nerve-centre or ganglion; all of which, being brought together in the head of the animal, constitute what is known as the *cephalic ganglia*, or *sensorium*, an incipient brain.

The function of this nervous system is not merely to respond to irritation applied directly to the body, but also to respond to certain stimuli, such as that afforded by sight and hearing, received at the sensorium through the organs of special sense, and thence transferred to the different ganglia. This new stimulus is called *sensation*, and it is one to which the ganglionic system responds with almost the same alacrity that it does to direct contact.

Leaving now the grand division of mollusks, we ascend to another division in the animal world, namely, the *Articulates*. It embraces such marine animals as the crab, lobster, and crayfish; and on the land, worms, centipedes, and all the numerous tribes of insects. The characteristic of the whole division is, that the body is made up of rings or segments, joined and moving one upon the other, and hence the name *articulates*.

The general plan of the nervous organization throughout this large division is that just described, and commencing with cephalous animals. It consists of symmetrically-arranged ganglia—a sensorium, and the necessary communicating nerves.

And what are the actions by which this improved nervous system, characterizing all this large class of animals, manifests itself?

Taking the two extremes in the class of well-characterized articulates, the centipede at the lower, and wasps and bees at the upper, we notice a wide difference in the complexity of the general organization, and a difference equally marked in the character of the corresponding actions. In the centipede, the general structure consists of a head furnished with certain organs of special sense, and a body made up of a series of segments—each, with the exception of the last, being a repetition of the others, and each being furnished with a single pair of legs.

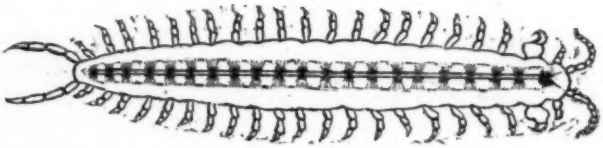


Fig. 2.—Sensorium and Connected Ganglia of Centipede.

To preside over these organs of locomotion, the nervous system is distributed as follows: Each segment is supplied with a double ganglion, or nerve-centre, all being arranged in regular order just beneath the alimentary canal, and in the head is placed the sensorium; all the different ganglia are connected by a fine double-nerve filament called the *ventral cord*, and through this means also all are in communication with the sensorium. So each ganglion is in communication with its own particular pair of locomotive organs, with each of the other ganglia, and with the sensorium.

The chief action of this animal consists in the movement of these organs of locomotion; and this it does in response to direct irritation from without, or in consequence of *sensations* received at the sensorium through the organs of special sense, and thence transmitted to the several ganglia. So long, then, as this nervous communication remains unbroken, the action of all the segments composing the body is harmonious, and is performed with a direct relation to the guiding influence of the sensorium. This is the normal action of the animal. But suppose, now, that the head, with the sensorium, be removed while the creature is in motion, the legs still perform their office, carrying the body forward in its accustomed manner until it meets an obstruction, when its progress is stopped, though the legs still continue to move. If the body be divided, similar results follow: the forward part moves on under the guidance of the sensorium, avoiding or overcoming obstacles according as sight or other sensations influ-

ence; the after-part of the divided body also moves on, but only in obedience to its own ganglionic centres, and without any guidance from, or relation to, the sensorium, or the anterior portion of the body.

Thus we see the ordinary movements of the animal continuing to be repeated with only that part of the nervous system in operation which is capable of producing *reflex action*. What the entire creature has been *accustomed* to do, the separate parts continue to do when cut off from the guiding influence of the sensorium. The same holds good even in some of the more highly-organized members of the articulate series. A remarkable instance is given by Dr. Carpenter, as shown in the *mantis*, an insect allied to the crickets, which performs its accustomed and very peculiar actions not only when the head is removed, but the segments of the body perform each its accustomed part, and no other, when the body itself is divided. So also a certain kind of water-beetle, after the sensorium is removed, remains motionless so long as it rests upon a dry surface; but, being placed upon the water, its accustomed element and stimulus, performs its accustomed movements of swimming, and with such energy as to strike aside its companions with great violence. These motions, which are repeated, as has been seen, under the influence of the ganglionic system alone, and by the simple process of reflex action, are termed *automatic;* and when these actions, though often more complex and varied, are repeated in the same automatic manner under the guidance of the sensorium, and under the stimulus derived from sensation, they are called *instinctive*.

Coming, now, to the higher species of articulates, we find the so-called social insects, and especially bees, furnishing the most wonderful examples of instinctive action; they construct for themselves habitations, some of them involving nice principles of geometry; they store up food for future use, and their whole economy seems, at first glance, to demand the presence and aid of even a rare intelligence; yet, on examination, it is found that no teaching is required, no thought nor memory is brought into use in these remarkable actions, but each insect goes to work without direction and without individual experience, and does at once, without hesitation, the first time as well as ever, that which is in its nature to do. "It acts according to its nervous organization."

How the insect comes by this *impulse to do*, is one of those seemingly simple questions which, in reality, includes the whole; it is the ever-recurring question regarding each new faculty as it makes its appearance in the series, and demands a few words in reference to the main theories involved. The term *instinct* is not to be taken, in its popular sense, as referring to all the actions performed by animals in distinction from those performed by man, but must be limited to those automatic actions which are performed without teaching or individual experience. Now this impulse, or instinct, as exemplified in the bee,

must, as was formerly supposed, have been directly impressed upon the nervous organization at the creation of the first bee, and transmitted by each succeeding generation, or, as contended by Herbert Spencer and others, the race must have become gradually endowed with it, by a constant repetition of those acts which each individual was stimulated to perform by its surroundings at succeeding times. The former method presupposes a *special creation* and endowment for each species of animals; a supposition generally rejected by scientific men as presenting insurmountable difficulties, and as not having facts within possible reach to sustain it; for no one has ever known of a special creation. The other method presupposes *development* in some of its various phases, which, although not without its difficulties, satisfies so many existing conditions, and is constantly helping to solve so many formerly insoluble problems, that scientific men are led to adopt it, provisionally at least, as probably true in its main features, and certainly of great importance as an aid in further investigations.

According to this theory, instinct is the aggregate or accumulated experience of each race of creatures in which it is found—is impressed by repetition upon the nervous organization, and is inherited alike by each individual of a race, causing their actions to be the same, generation after generation, unless changed by necessity from changed surroundings. This is the mode of action characterizing the large class of animals whose highest nervous development is the sensorium. It embraces the cephalous mollusks and the whole division of articulates; and its highest development is reached in insects.

Ascending now another step in the series of animated forms, we find again an advance in the nervous organization suited to the still more complex action and consequent needs of the animal.

Without following out in detail the gradations which take place in passing from the articulate to the vertebrate series, we find in general terms the following changes to have occurred; and, as an example, one of the first and simplest of the series may be taken, namely, the fish. Instead of the *ventral cord*, with its interrupted series of ganglia, as in the centipede, we find in the fish a *spinal cord*, existing as a continuous line of ganglionic matter, inclosed in a fibrous sheath of white conducting matter, and the whole protected in the bony canal formed for it by the beautifully-arranged pieces which make up the *vertebral column*, or back-bone. From this continuous ganglionic centre nerves are given off at different points, as they are needed to supply the different muscles of the body, and especially those of locomotion. We find the sensorium enlarged to preside over the improved organs of special sense, the optic ganglia still being much the more important; and we have two *new* ganglionic masses *added*, the *cerebrum* in front of the optic ganglia, and the *cerebellum*, placed just behind them. Concerning these, it may be remarked that the latter, although its function has not been so clearly demonstrated as many

other portions of the system, shows such marked relations to the complexity and perfection of the movements of which any animal is capable, as to render it nearly certain that its use is to regulate and coördinate muscular action; while the former, as marking a grand advance in the psychic endowments of living creatures, constitutes the most important addition to the nervous system hitherto found.[1]

FIG. 3.—BRAIN OF FISH: 1. Olfactory Ganglia; 2. Cerebral Ganglia; 3. Optic Ganglia; 4. Cerebellum; 5. Spinal Cord.

Here, for the first time, inclosed in its bony covering, we have an organ possessing, even in a rudimentary form, the principal parts of a complete brain. Of these parts the cerebrum, which is found as merely rudimentary in the fish, now takes the precedence in interest and importance—from fishes to reptiles, from reptiles to birds, from birds to mammalians, and all through the mammalian tribes, from the imperfect marsupial upward to the anthropoid apes and man, we find in the main, an unbroken line of increase in cerebral development, and corresponding increase in intelligence.

Then, again, it is of interest to inquire the manner in which this new faculty, intelligence, makes its appearance along with the improved nervous organization, and how it differs from the instinct of the classes below.

According to the eminent authority before referred to, as instinct is the aggregate experience of the *race*, accumulated and impressed upon the nervous system by innumerable repetitions, inherited by each individual of the race and available all at once, so intelligence is the aggregate *individual* experience and is available only as acquired, though the facility for acquiring it varies according to the nervous organization. Both instinct and intelligence may exist in the same individual, but generally, in proportion as actions governed by intelligence become numerous, those governed by instinct decrease in number and importance. In observing the nervous organization of the

[1] As expressed by Mr. Fiske, in his "Cosmic Philosophy," the cerebellum presides over *space* relations, while the cerebrum presides over *time* relations.

centipede as the representative of a dawning instinct and its appropriate manifesting organ, the sensorium, it was found that reflex action, characteristic of acephalous animals, did not cease when the head and its special ganglia appeared, but that a large share of its actions was still purely reflex in character, even those prompted by its small and imperfect sensorium being but little raised above the reflex and into the region of instinctive actions; and that the ganglionic system and reflex action were continued all through the higher mollusks and the whole series of articulates, only diminishing in importance as the sensorium and instinctive action increased. So in the commencing vertebrate series, we find the nervous organization of the preceding races continued—that for reflex action being represented in the spinal cord, and that for instinctive action being continued in the sensorium; not only so, but in proportion as the cerebrum remains small and undeveloped, and the sensorium predominates, do instinctive actions remain in the ascendant both in number and importance. This is found to be true in all the lower orders of vertebrates—fishes and reptiles; and even in the lower mammalians, although the cerebrum may outweigh the other portions of the brain, still a very important part of the actions manifested is instinctive. As an example of this in birds,

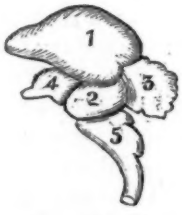


FIG. 4.—BRAIN OF PIGEON: 1. Cerebrum; 2. Optic Ganglia; 3. Cerebellum; 4. Optic Nerve; 5. Spinal Cord.

may be mentioned the chick, which breaks its prison of shell with its beak and immediately runs about, sees and picks up its particle of food with unerring certainty without teaching or experience, hears and answers the call of the mother-bird, and scrambles toward her for protection although it may never have seen her. Birds also possess in a remarkable degree the impulse, akin to that of insects, for preparing elaborate habitations; but unlike the insect races they add a certain degree of intelligence to their work, varying it in form and material according to locality and surroundings, and even finishing for their own use that which others had left incomplete and abandoned. In proportion as instinct ceases to predominate, the work becomes less uniform; and so it may be observed in general, that in proportion as the habits of a given race are fixed and automatic, does each individual conform in its action to that prearranged method, and we know what each individual under given circumstances will do; but, as intel-

ligence increases and a larger range of actions is performed, this power to predict how any individual will act is gradually lost.

Advancing step by step upward in the mammalian series, certain changes in the development of the cerebrum occur, accompanied in each instance by the introduction of new faculties or the improvement of old ones. Throughout the lower orders—fishes, reptiles, and birds—the cerebrum, though constantly increasing in relative size from mere nodules of gray matter less in size than the optic ganglia, up to masses of much greater bulk than the sensorium, still retains the same general appearance—two smooth oval bodies, one on each side of the median line, and gradually approaching each other as they enlarge until they meet, then extending forward and backward so as more and more to cover in and hide the sensorium. These represent the *hemispheres;* and this is the condition of brain which is found in the lower mammalians. Associated with this cerebral development we find a psychical condition not very far advanced beyond that already considered as pertaining to birds; namely, action partly prompted by instinct, and partly controlled by intelligence, as especially seen in the *rodentia*, or gnawing animals. The perfection of instinct and want

FIG. 5.—BRAIN OF RABBIT (*Rodent*): 1. Olfactory Ganglia; 2. Cerebral Hemispheres; 3. Cerebellum; 4. Spinal Cord. Other parts of Sensorium covered by Cerebrum.

of reasoning power in regard to certain actions are well illustrated in an example quoted by Dr. Carpenter. It is that of a beaver which a gentleman kept in his house, and who, notwithstanding his unfavorable surroundings, would exercise his instinct for dam-building on all occasions; for materials he appropriated brooms, warming-pan, walking-sticks, baskets, boots, and books, or in fact any thing portable within his reach, arranging them in the most approved style of beaver architecture, although he had never witnessed the process in others. He exercised the same skill, also, in preparing himself a dwelling. The absurdity of the whole process from a *reasoning* point of view

was obvious from the fact that he had no access to water, and was already comfortably housed. He was simply working out what was impressed upon his nervous organization by countless generations of dam-builders before him, independent of circumstances or uses. In this class, however, are commenced two grand improvements in the cerebral development: first, the uniting of the two parts constituting the hemispheres by a broad band of fibres, known as the "*great transverse commissure*," indications of which appear in the rodents; and, second, "indications of a '*middle lobe*' marked off from the anterior by the fissure of Sylvius." To these soon are added the "*convolutions*," or corrugation of the outer or cortical layer of the hemispheres, so as to secure more surface of active nerve-material without additional bulk; and lastly, in the apes, appears the commencement of the *third* or "*posterior lobe.*"

In the human brain no addition of parts is presented, but only improvements in those parts found in animals next below. One of these improvements is the more perfect communication established between the different parts composing the brain; the great "transverse commissure" connecting the two hemispheres is much better developed than in any of the preceding races, also the fibres connecting the cerebrum with the sensorium upon which it lies; the "convolutions," only indicated by slight depressions even in monkeys and apes, become conspicuous in the human brain, giving it the appearance of being gathered up in deep folds; and the "posterior lobe," which, as we have seen, first makes its appearance in the highest apes, is much increased in man, even in the uncultivated tribes, as is also the comparative bulk of the whole cerebrum.

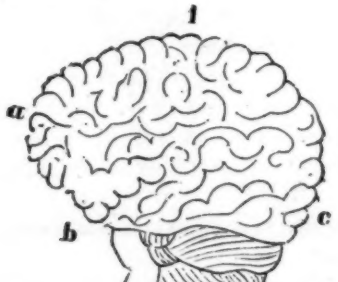


FIG. 6.—HUMAN BRAIN: 1. Cerebrum: 2. Cerebellum; 3. Spinal Cord. Sensorium covered by Cerebrum; *a*, *b*, *c*, Anterior, Middle, and Posterior Lobes of the Cerebrum.

These various improvements, gradually succeeding each other, are accompanied by psychical developments equally marked; gradually the strong instincts and limited perception of surroundings, which

tend to make all the individuals of a class alike in physical and psychical endowments, give place to more complex sensations, gathered from a wider range of surroundings. The cerebrum begins to take cognizance of these sensations, and to give its approval, before they are translated into actions; memory dawns—hatred, fear, anger, and revenge, are born; a certain adapting of means to ends gives evidence of commencing reason; affection, love of approbation, joy, and sorrow, all these appearing in the races most associated with man, proclaim the presence of faculties and endowments far above the plane of mere instinct, and bordering close upon attributes usually applied to *soul* alone, and in its more dignified estates.

Examples of such endowments in the brute races can hardly have escaped the notice of any intelligent observer. In the faithful dog, who at a word from his master collects the stray flock in the stormy Highlands, or brings in the helpless and perishing traveler from the snowy Alps; who shields his child playmate from the passing danger, or rescues him from threatening death; who, himself hungry, guards food for others; who with quick perception notes and shares his master's varying moods, and who metes out justice for the weak against the strong, we behold in humble guise a dawning soul, with which no truly noble soul need wish to ignore kinship.

To note all the improvements in the physical organ of mind in man, and point out the vast psychical advances which are found in him, compared with the best of the races beneath him, would far exceed our limits. We may, however, notice here that, as in his nervous organization, no distinctly new parts are discoverable, but only general growth and development, and especially vast increase in the size and working capacity of the cerebrum, together with improved lines of communication between the different parts of the brain, so in the psychical manifestations which this enlarged and better-developed brain exhibits, no faculties are discovered beyond what these various developments in structure render possible. Does man possess intelligence? It is found also in the lower tribes. Memory? Many races of animals possess it. Reason? No definition of it can be formed, consistent with its exercise in man, which can debar it from some feeble exercise in his more lowly companions. Up to the point which their organization permits, they possess and exercise faculties akin to those of man. But it is in the degree and perfection to which these faculties attain that the superiority of man is evident; and here the difference is vast indeed. The intellectual superiority of an ordinary man over the most sagacious animal, which nevertheless can scarcely be taught the simplest relation of numbers, is too vast to be readily comprehended; but so is the difference immense between the reasoning powers of an infant and a man, or a Hottentot and a Cuvier or Laplace. If a dog cannot be taught simple arithmetic, neither can a Hottentot be taught optics nor analytical geometry, nor be made to

take in the idea of "quantitive reasoning" nor "correlation of forces." The dog is capable of improvement, limited only by his organization; the Hottentot only by his, and the child of a large-brained and cultivated ancestry by his. The difference in these possibilities, however, can only be comprehended upon reflection. The most intelligent animal, or even the savage man, bears relations to no surroundings beyond the mere *seeming* of things upon the few acres or miles traversed by his race or tribe; the sun and moon are only what they appear; they rise just beyond the mountain, and they go down in the forest. The thunder and the tempest are incomprehensible, or are the voice and breathings of an angry God. The philosopher, or man of science, on the contrary, holds converse with all objects, animate and inanimate; all peoples and their works, both present and past, upon the surface of the earth. He explores its depths, and calls up before him the generations which peopled it ages on ages past. The microscope brings before him the world of the infinitely small, and the telescope reveals the worlds of space. With the spectroscope he questions the stars, and they give intelligible reply. Such, and a thousand-fold more, are his surroundings; and it is to express his relations to these, to the complex impressions and sensations to which they give rise, and the reflections and aspirations which they inspire, that the brain of the philosopher must be adequate.

We have thus noticed the more prominent structural changes as they occur in the nervous system, from its simplest form to its highest development, and also the corresponding psychical manifestations, which each advance in structure rendered possible. We have seen the lowly creature, endowed with its single nerve-centre, and its radiating nerve-filaments, expressing all its relations to the outer world by simple *reflex action;* and, if, as we should expect, the order of appearance in Nature corresponded with the order of development, for untold ages all over the silent, ocean-clothed earth, no higher form of life, and no higher expression of soul, was present. Gradually, by many a minute addition, in response to improved surroundings and new requirements, new organs appeared, until at length there existed a creature of definite form, with organs of sight and hearing, as well as touch and locomotion. The old ganglionic nerve-system, with its simple reflex movements, was still retained; but, to express the many new relations to the outer world which its gradually-acquired organs made possible, additional nerve-centres were required, and the *sensorium* assumed form and use. The series of actions performed through its promptings we call *instinctive.* Then for unknown ages sense-impressions, stimulating to instinctive action, were the highest expressions of soul upon the slowly-emerging earth.

But, again, improved surroundings—the dry earth, with forest, field, and flower, the brighter sunlight and the purer air, demanded new organs to appropriate and new senses to enjoy; and a race ap-

peared with improved organs of sense to receive impressions from this better outer world, improved modes of action, and above all in place, and superior to all in function, an organ of intelligence was added. The old methods of soul-manifestation continue; both reflex and instinctive action find their appropriate place in the higher organization; but they are not sufficient for the numerous and complex relations which now existed between the creature and the outer world; then the cerebro-spinal system comes into being, consciousness becomes perfected, intelligence established, and reason dawns.

Again, ages elapsed in gradual changes, until at length man, the crowning excellence, appeared—an upright form, a powerful brain, a soul capable of tracing causes, and even seeking to find out the First Cause. He was the first to place an ideal—his highest conception of good—before himself, and say, "Now for this will I strive;" the first of all the long line of sentient beings to aspire after a higher life; the first to say within himself, "I shall die," or ask, with ever-increasing interest, "Shall I live again?"

And what is the relation of science, especially as represented by the doctrine of evolution, to this aspiration after a future life? The objections raised against the doctrine by the religious world—the uninstructed part, at least—are that it banishes Deity and tends to materialism.

If by banishing Deity is meant that conception of him which particular sects or peoples have obtained, and are each desirous that all the world should have, the objection may or may not have foundation; but, if it is meant that the doctrine shuts out a great first and adequate cause for all the grand and orderly series of events and existences in Nature, nothing could be further from the truth. The desire to seek for causes is one of the developments of the human mind, increasing in direct ratio with the increase of intelligence. Brute intelligence exhibits no such desire. The savage mind does not rise far into that sphere of intelligence which demands causes; it is only as a higher reasoning power dawns that analysis commences, and causes are sought after; and the higher the intelligence and stronger the power of reason, the more imperative the demand for causes, and the more perfect the comprehension of them.

What is true of causes in general is true in a still greater degree of remote causes, and of a first cause; and hence that which we should expect to occur is found to be the fact, namely, that the scientific men of the present time, the well-developed and well-cultivated minds in all departments of learning, but especially in physical science, are the ones most fully established in an intelligent belief in an adequate first cause. The time is past in which the feeblest artificial works found upon the surface of a single planet, even to the flint-hewn weapons of an unknown race, must have assigned for them a competent originator, and yet man himself, with his complex organization, the long line of organ-

isms of which he is chief, the planet on which he dwells, the system to which it belongs, and the whole vast system of systems sweeping in unimagined circles through space, all be supposed to exist, and have no architect and no supporter. Such is not the deduction of science, and such is not the conclusion at which the most skilled interpreters of Nature have arrived. In examining any artificial work, it is an instinct with man, and his reason approves, to assign for it a conscious and intelligent cause; and he knows that the cause exists in *mind*, for without mind nothing could be planned or originated. Not only so, but in every instance we judge of the *character* of the originating *mind* by the product. A great and noble work is not originated by a feeble and undeveloped mind, nor a crude and imperfect work by a large and well-disciplined one.

We judge similarly in regard to every work, from the crude utensils of the "cave-dwellers" to the mighty products of a Michael Angelo, a Shakespeare, or a Laplace. So, in judging of works compared with which the mightiest works of man are as mole-hills, whose beauty it is the highest exercise of his genius feebly to copy and represent, whose method and arrangement it is the life-work of the most exalted intellects to discover, and whose extent, either in time or space, he still gropes to find the unit of, we assign for cause a corresponding soul; and he who comprehends best the work is capable of understanding best the architect.

The gods of sects and specialties may perhaps be failing of their accustomed reverence, but, in the mean time, there is dawning on the world, with a softer and serener light, the conception, imperfect though it still may be, of a conscious, originating, all-pervading, active soul—the "Over-Soul," the Cause, the Deity; unrevealed through human form or speech, but filling and inspiring every living soul in the wide universe according to its measure: whose temple is Nature, and whose worship is aspiration.

Science, then, so far from excluding God from the universe, demands him as an ever-active power; but, as man can only know him through his works, and as the universe is yet comparatively unknown to him even in his highest condition, and must remain so while he is confined to earth, it follows that our knowledge, and even our conceptions of him, must be limited and imperfect, and our appreciation of him correspondingly so.

Is there, then, reason, in harmony with science, to expect an existence under more favorable circumstances for a knowledge and appreciation of this originating soul whom science itself demands?

As interpreted by the doctrine of evolution, we find man, as he now exists, with his physical organization and advanced psychical being, the product of a long series of developments. He has arrived, however, only at a certain point in the ascending series; from that point he easily reviews the whole long line beneath him from the very

beginnings of organization and life, and admires its grand and orderly procession; but, reaching out forward, he seems to find nothing within the scope of his physical senses. He sees, however, that the series is not ended, for reason assures him that even for the material universe there is, somewhere beyond, an architect whose skill and wisdom he is only commencing to appreciate, but still more, when he beholds the gradual unfolding of the world of soul, with its instinct, consciousness, intelligence, memory, reason, feeling, and aspiration, and considers the possibilities which still may lie enfolded there, is he lost in admiration and wonder at the great centre-soul, the author of all these attributes. And what is to span over the abyss, or even reach out toward this ineffable soul? Is he himself to cease when the material organization wears out?—and consciousness, memory, reason, and, higher, nobler and purer than all, heaven-born aspiration, the crowning development of countless ages, do they all go out in darkness just at the dawning? or, rather, do not the organization of elements and their development into life and movement, the gradual dawning of instinct and reason, and, lastly, of an aspiring soul, give promise of further development under more favoring circumstances for approaching, knowing, and appreciating the great central, causal, all-pervading soul?

For scientific proof of this after-life and future development, the whole world is looking, nor is there any thing unreasonable in the expectation. The orderly steps in the series of development suddenly end with the birth of a soul capable of inquiring after its Author, and aspiring to a continuous life. *Is* it, then, the end of the series, or must there not be further steps approximating toward the central soul, and observers have not searched aright, or means of observation been imperfect or misused? As, in our solar system, the "law of distances," found to exist among the planets, caused astronomers to look for another body in the huge space between Jupiter and Mars, who were rewarded by the discovery of the Asteroids; or as perturbations in the motions of Uranus caused them to look for a planet beyond its orbit, and Neptune was found; so, with equal reason, may psychologists infer the existence of a whole series of superior beings reaching onward toward the Infinite; and who shall deny the possibility of their discovery? The development of man is constantly leading on to the appreciation of more and more subtile elements and effects; the laws which govern the atmosphere—light, sound, and magnetism—which could not have been understood in the infancy of the race, are being unfolded; colors which our remote ancestors could not perceive, are being differentiated; and sounds, which to them were unmeaning noises, or were not discerned at all, to our more refined and better-developed senses convey impressions of pitch and harmony. Such advance in the development of the ordinary senses, not to discuss the possibilities of an internal and still higher sense, gives promise of

future known relations to that which is subtile in the domains of biology and psychology, beyond that which has hitherto been attained.

In this view Science need not despair, and has no right to give over its efforts nor neglect its opportunities to obtain appreciable evidence, however slight it may at first appear, of a future life—one which the doctrine of evolution demands should be a higher development, one of greater possibilities than this. The aspiration after such a life is as much a development of the soul as is intelligence, or reason, or a desire to know causes, and there is the same reason to believe that it has its foundation in a corresponding reality.

And, great as have been the triumphs of science hitherto—great as has been the light which the grand thought of evolution has thrown upon the whole plan and system of the universe—nothing hitherto accomplished could compare in grandeur with the physical demonstration of a higher mode of life and action than that attainable with our present organization and present limitations; a demonstration which would enable man to lie down to sleep with the *knowledge* that he will awaken to an enlarged and ever-enlarging, conscious, future life.

ADDRESS TO MEDICAL STUDENTS.[1]

By Rev. E. A. WASHBURN, D. D.

I AM glad of the privilege, gentlemen of the Medical College, of meeting to-day so many who are masters and students in the school of science. For if, as I believe, all our studies, whether of Nature or mind, are only chapters of one book, there can be nothing wiser in our day, when the growing mass of learning almost compels a microscopic research and somewhat of a microscopic bias—nothing wiser than at times to interchange our points of view. It is, indeed, one of the phases of that heredity, of which so much is said at present, that our callings bequeath their mental habits, so that the clergyman seems often born without the power of inductive reasoning, and the naturalist with a suspicion of all that cannot be analyzed by his blow-pipe. Yet I am sure that you are of a larger school than this; and in that feeling I venture to put before you a few thoughts on the mutual relations of scientific culture. I shall not try your patience by a treatise on the Mosaic cosmogony or evolution; and, indeed, I must ask your allowance beforehand, if I betray in my remarks that surface knowledge of gases or nervous tissues, not strange to one more busied with Greek aorists and primitive-church deposits. It is your noble calling to be students in that branch of science, perhaps the most fruitful of

[1] Delivered recently to the graduating class of the New York College of Physicians and Surgeons.

discovery to-day, which explores the laws of the highest organic life. If I can point out a few of the common features which give a meeting-ground with you for one who is, like myself, a physician of the soul—for studies that bear on the riddles of our mental life and the largest aims of moral education—my essay will not be thrown away.

It is plain to all that the marked feature of our modern culture is the enthusiastic study of Nature; and the fact demands our impartial thought. This change, even within the last thirty years, is a striking one. It comes in part from the magnificence of the discoveries gained in every part of natural inquiry. It comes again from the reaction of the mind, after a time of overstrained ideal pursuits; nor is it strange, when the philosophy which began with noble thinkers had evaporated at last into a misty pantheism, that we should ask a more robust sense, and a positive knowledge. It is amusing to meet to-day those who awhile ago were talking of the infinite soul in man, and are now quite proud of their pedigree from a West-African ape. But I attribute this feature of our culture not merely to such reaction. It betokens a solid growth in the method of inquiry. Although I distinguish it from many of the theories which call themselves science, yet the principle which begins with the study of facts, verifies them by sure experiment, and rests in ascertained laws, is the key of all discovery. Our modern intellect did not, indeed, originate it. Nor can I ever admit that the great thinkers of the past have not done immeasurable service in their spheres of knowledge; rather, I claim that there is not a single foundation truth, in regard to the mind or moral nature, which was not known, even before a Plato or an Augustine. Our philosophy does not give essential truth; it only opens it in its clearer relations. The fixed stars have shed the same light aforetime, although the glasses of to-day have pierced into the nebulous fields. But it is the peculiar character of natural science, and the grandeur of its march on this high-road, which have established, as never before, its critical method. You are familiar with this in the wide range of inductive study. The knowledge of the heavens is quite another thing to us than in the day when Aristotle reasoned from the ideal perfectness of the circle to the planetary motions; and "made the world," in Bacon's phrase, "out of his categories." Or, to illustrate from your own field, the ancient theories of material and spiritual substance, which led to such fruitless speculation even to recent days, have been exchanged for exact analysis.

But this method is not confined to the interpretation of Nature; it is the common law of advance in all knowledge. Mental science must now begin with the related facts of biology and psychology, in order to rise by clear analysis to the laws of thought or will. History obeys the same principle, and it has so passed, since the day of Niebuhr, out of the cloud-land of legend to *terra firma*. Our vast researches into language have come from the dismissal of the old

hypothesis of a primitive tongue and the correlation of all the facts gathered from all the kindred forms of speech. It is the same with social science. And although I am aware of the notion of many doctors, both of divinity and medicine, that theology is a fixed deposit, as distinct from inductive knowledge, and indeed that there is an eternal conflict of religion and science, yet I am bold to say that it is a vulgar error. There is a more palpable movement in the science of Nature, because it has to do with material forces, while the theologian explores the more subtile laws of thought and moral history. We do not deal with scalpel or microscope, yet we recognize the method of analysis. It might be a curious pursuit if you should study medical history from the day of Galen, through the middle age, and note how the same speculative notions of soul and body entered into the current dogmas of the Church and the healing art. The central truths of Christianity are always the same; but Biblical criticism, the comparative study of Hebrew or Christian epochs, the domain of doctrinal thought, are growths of the human mind, and every advance has been the fruit of experimental searching. And if we have some clergymen as guiltless of modern ideas as the Englishman who moved the risibles of a scientific circle by claiming that the fossils of the caves were the bones of the rebel angels, possibly you may have a few doctors of medicine almost unable to appreciate the scientific criticism of the four Gospels.

But, as we have thus recognized this law of method as the fruit of our culture, we shall be able to see the interdependence of all these branches of knowledge. All our gains are helpful to each other. I might sum the vast history of science in a word—that it has taught us the harmony of law, not only in the correlation of natural forces, but of the moral and social forces of human life. But I look more especially at the studies which employ your profession, as they have shed such light on the marvelous secrets of the inner man. The cunning laws of cerebration; the wondrous rhythm that runs between the several powers of memory, feeling, will, and the sensitive nerve-centres; the dependence of thought on the supply of the chemical brain-food; the explanation of the riddles of our dream-life; the relation of our mental functions to the loss or decay of our organs; the phases of disease as affecting voluntary action—all these are as needful a study for the intellectual or the Christian thinker as for the naturalist. These researches have not only cured many mistakes of our psychology, but have given us sounder views of life and education. It is not too much to say that our theories of social and religious culture have been far too often affected by a partial view of our spiritual nature, which lost sight of its dependence on the body and the healthy laws of action. But while I gratefully acknowledge this debt, I hold that our scientific culture will, if faithful to its aim, lead us to a nobler knowledge of those truths that pass beyond a bald materialism. I

can only touch here upon this wide subject. If I were to seek an argument against the modern deniers of a Divine Maker and Providence, I should turn to science itself as furnishing its best ground. The result of our study of Nature, it is justly claimed, is only the knowledge of phenomena; but in this claim science has rid us forever of the notion of material substance; it has resolved all into one original, persistent Force; it has thus lifted matter into a domain above the physical, and by its own induction brought us back to the necessary truth, which we can only interpret by our own personal intelligence and will. If evolution, whatever its amazing chain of growth, is forced to admit that the principal world-stuff has in it the capacity of all the thinking, conscious, moral being begotten from it, evolution is but a vague name for the living action of a living God. And when I sum, again, our results as to the human organism, all our knowledge of the fitness of the cerebral mass and each fibre of the spinal net-work to the motions of the unseen life, so far from proving thought a function of the brain, or will a shock of the nerve-power, has only refined the body into the perfect vehicle of the indwelling spirit. Nothing is more satisfying to a believer in facts above Nature than that chapter on the "Substance of the Mind," where the apostle of English Positivism, Mr. Spencer, gives us as the outcome of his analysis, that when we talk of material or spiritual substances, it is indifferent whether "we express those in terms of these, or these of those;" yet, as thought cannot be dissected like the gray matter of the brain, it is sounder science to say that the living force is another than the physical fact.

But I cannot linger on these questions. Enough if I look forward in this light to the most harmonious results. We need not expect at once a reconciliation of all discords. Much must be done before that is reached. The clergyman has to learn fully that the Word of God is to be studied as the oracle of the great truths of man's spiritual history, not rashly made the rule of exact science. The naturalist must learn that there are facts of conscience and of human life more sacred than the guesses of his theory, which he must touch with reverent hands. Indeed, I have sometimes thought if the clergy could ramble with Mr. Huxley over the glaciers, and Mr. Huxley would take an excursion into the fields of Christian history, we should have better clerical sermons; and better "lay sermons." Science will work its own cure at last. It is not probable that there will be less prayer on account of Mr. Tyndall's "prayer-gauge," so long as it is the bidding of the heart of man. It is not probable, if, as a witty doctor has lately hinted, we measure the varied genius of Homer, Spenser, or Béranger, by the slower or quicker respiration, that we shall read the "Iliad" or "Faerie Queene" with less delight. It is not probable that all our discoveries of the ape period will kindle our interest so much as the history we remember far better of the struggles and divine triumphs

of the full-grown man. Let Science go on with its keenest analysis. It will return, when it is completed, to the living synthesis. If, with all our processes, we cannot manufacture a man, if even the mineral water we concoct is not quite the same as Nature brews in her laboratory, much more shall we give up the fruitless task of dissolving the ultimate facts of mind and life. I have been struck with a sentence of the late Mr. Mill, in his autobiography, where he speaks of a long stage of mental depression which destroyed his zeal for all his favorite studies. "I saw," he says, "that the habit of analysis tends to wear away the feelings. My education had failed to create these feelings in sufficient strength to resist this dissolving influence, while the whole course of my intellectual cultivation had made such analysis the inveterate habit of the mind. I was thus left stranded at the commencement of my voyage, with a well-equipped ship and a rudder, but no sail; without any desire for the ends I had been so carefully fitted to work for." That is the autobiography of our time, of its strength and of its weakness. Let such experience teach us the honest pursuit of science, but teach us also its limit. Our age will gather up the real gains of its knowledge. We shall have learned many of the laws of our being; we shall apply ourselves to a broader culture of the mind; we shall feel a more earnest interest in all aims for the improvement of the race. But we shall prize no less the treasures of letters and art bequeathed us by the past; the ideal truths which have employed the wise and good; and, above all, that Christian faith which has inspired the richest knowledge of mankind, and without which our best culture will be as dead as the fossils of a prehistoric cavern.

Such, gentlemen, is the result I anticipate for the next period of our scientific growth. Pardon me if I have given you too long or too dry an essay; but let me beg you to receive it as the conviction of one who feels a generous sympathy with all the real aims of his time. This is the best spirit of your noble profession. If you so pursue it, as honest interpreters of Nature and reverent worshipers of Him who is above Nature, you will make it a sacred ministry for not only physical knowledge, but for the service of God and man.

THE DEEPER HARMONIES OF SCIENCE AND RELIGION.[1]

THERE are two very opposite parties among us at the present day, whose language is in one respect very strikingly similar. The Christian Church has from the beginning spoken with a certain contempt of learning. "The wisdom of the world," "oppositions of

[1] This article appeared in *Macmillan's Magazine* under the title of "Natural Religion."

science falsely so called," "to the Greeks foolishness;" these are the phrases of one of the earliest and highest of Christian authorities. In our own country the two most powerful of Christian movements, Puritanism and Evangelicalism, have been distinctly marked with this characteristic feature, although it might be possible to mention one or two learned Evangelicals and several learned Puritans. That there have been, and are, a vast number of men at the same time Christian and learned, does not affect the fact that Christianity holds itself aloof from and in a manner superior to learning. Such men, where their Christian feeling has been intense, have often spoken disparagingly of their own learning, as of a thing of little value, and have taken a pride in placing themselves on a level with the ignorant. If it is true that eloquent vindications of learning from the Christian point of view might be quoted, lofty assertions of the sympathy of Christianity for whatever is true and elevated, such assertions do not prove so much as is proved by the necessity of making them. If we admire them, it is rather because we love learning than because we love Christianity. We admire them as noble deviations from the Christian tradition, in a point where we have a misgiving that Christianity may be narrow. Yet this contempt for *learning* no Christian would admit to be equivalent to a contempt for *knowledge*. Knowledge, a certain kind of knowledge, Christians maintain to be the only thing worth having. Wealth, power, every thing that is counted desirable, they despise in comparison with a certain kind of knowledge. It is among these things comparatively despicable that they class what is commonly called learning. They despise it not *as* learning, but as learning comparatively worthless in quality, as being but a counterfeit of the true learning which it is happiness and salvation to possess.

Now, in this respect quite an opposite school hold the very same language. Scientific men resemble Christians, in treating with great contempt what goes by the name of learning and philosophy, in comparison with another sort of wisdom which they believe themselves to possess. Like Christians, they are no contemners of knowledge; on the contrary, in praise of knowledge they grow eloquent, and use language of scriptural elevation. "Wisdom is the principal thing, therefore get wisdom; and with all thy getting, get understanding." It is their unceasing cry that all good is to be expected from the increase of true knowledge; that the happiness, both of the race and individuals, depends upon the advance of real science, and the application of it to human life. Yet they have a contempt for learning, which is just as Christian in its tone as their love for knowledge. "Erudition" and "philosophy" are terms of contempt in their mouths. The first they consider to be, for the most part, a criminal waste of time; philosophy they denounce as consisting mainly of empty words, and offering solutions either imaginary or unintelligible of problems which are either imaginary or unintelligible themselves. In some scientific

men this feeling of contempt for learning is concealed; they will profess to admire scholarship and erudition, speaking of it as a graceful accomplishment; and it is only in unguarded moments that they betray their conviction that it is nothing more; others proclaim it loudly, and some even wish to bring public opinion to bear upon the matter, so as to prevent as an immorality the acquiring of useless knowledge.

Thus, the old religious school, and that new school whose convictions we see now gradually acquiring the character of a religion, agree in combining a passionate love for what they believe true knowledge, with a contempt for so-called learning and philosophy. The common enemy of both is what the one school calls, and the other might well call, "the wisdom of the world." But though agreeing so far, these two schools hate their common enemy much less than they hate each other. For each regards the "true wisdom" of the other as worse and more mischievous than the wisdom of the world which each rejects. To the scientific school the Christian γνῶσις is a mystical superstition, compared with which "learning and philosophy" are science itself. To the Christian, modern science is a darkness compared with which the science that St. Paul rejected might almost be called Christianity.

Nothing is so terrible as this clashing of opposite religions. Differences on important subjects are always painful, but the direct shock of contrary enthusiasms has something appalling about it. That one man's highest truth should be another man's deadliest falsehood; that one man should be ready to die in disinterested self-devotion for a cause which another man is equally ready to oppose at the sacrifice of his life; this is a horror which is none the less horrible because it has often been witnessed on this perplexed planet. But often it has been seen, long after the conflict was over, that there had been misapprehension; that the difference of opinion was not really any thing like so complete as it seemed. Nay, it has often happened that a later generation has seen the difference to be very small indeed, and has wondered that so much could have been made of it. In such cases the mind is relieved of that fancy of a radical discord in human nature. We see that self-devotions have not really clashed in such fell antagonism. We see that with self-devotion there may mix less noble feelings, and that the immitigable hostility of religious strife may be caused by a mixture of ardent conviction with some impulses less noble, with some that are blamable and some that are even ludicrous, with mere pugnacity, with the passion of gratifying self-importance, with the half-noble pleasure that there is in fighting, and the ignoble pleasure that there is in giving pain.

It would certainly be hard enough to show that the present strife between Christianity and science is one in which insignificant differences are magnified by the imagination of the combatants. The

question is nothing less than this, whether we are to regard the grave with assured hope, and the ties between human beings as indissoluble by death; or, on the other hand, to dismiss the thought of a future life as too doubtful to be worth considering, even if not absolutely chimerical. No reasoning can make such a difference into a small one. But even where the differences are so great, it may still be worth while to call attention to the points of agreement. In our penury of truth we ought to make the very utmost of our agreements. Let us rescue whatever we can from the waves of doubt; sailors thrown shipwrecked on a desert island must save what they can, not what they would. If there is some truth, however small, upon which all can agree, then there is some action upon which all can unite; and who can tell how much may be done by any thing so rare as absolute unanimity? Moreover, if we look closely, we shall always find our agreement to be more than we had expected. It seems as if men valued difference of opinion for its own sake. We seem not to care for any doctrine that is not controvertible. We talk with contempt of platitudes and truisms. Platitudes and truisms do not work up into interesting books; but, if our object is to accomplish something for human life, we shall scarcely find any truth serviceable that has not been rubbed into a truism, and scarcely any maxim that has not been worn into a platitude. But men seldom apply to truths this test of practice; they try them by the other test, which is the test of talk and debate. Thus it happens that ten points of agreement seem less important in most assemblies than one point of difference. Why is it men do not discover by experience the waste that is caused by this method? Either they must have a great deal of time on their hands, or else they have most unreasonable expectations from controversy. But I return to my point.

We are all familiar with the language used by Christians in disparagement of learning. God, they say, has revealed to men all that is essential for them to know. By the side of revealed knowledge what the human intellect can discover for itself is of little importance. If it seem to clash with revelation, it is mischievous; if not, it may be useful in a subordinate degree. But at the best it is contemptible by the side of the "one thing needful;" and the greatest discoverer that ever lived is a trifler compared with the most simple-minded Christian who has studied to fulfill the requirements of the gospel.

There are indeed a true erudition and a true philosophy, the subject of which is God's revelation itself. Scholars, profoundly read in the sources of theology, whether they be supposed to be the Bible or the Fathers of the Church; philosophers who have made the Christian revelation their basis, or have collected and elucidated the evidence of it—these are truly wise, and escape the censure of frivolity under which secular learning lies; but even these, illustrious and venerable

as they may be, will acknowledge that there is a wisdom beyond their own, which the humblest Christian may possess, the wisdom of simple belief and love.

We are less familiar as yet with the invectives of scientific men against what has long passed for learning and philosophy in the world. Different sections of the scientific school bring the accusation in different language. Yet the same feeling, the same strong and contemptuous conviction, pervades the whole school. What they reject and assail is, in two words, knowledge based on authority, and knowledge wanting an inductive basis.

That the utterances of great and famous philosophers are to be taken as truth; that in science, as in the civil law, the *responsa prudentum* have a binding force; has been accepted in some departments of knowledge up to the present day. Long after the authority of Aristotle had been shaken, new thinkers were allowed to occupy a similar place in some branches, and from Descartes to Hegel a sort of monarchical rule has prevailed in metaphysics. The scientific school tolerates nothing of this kind. Not that it refuses to reverence superior minds, not perhaps that it is altogether incapable of yielding to the temptation of trusting a particular authority for a while too much, or following a temporary fashion. But as a general rule it rejects as a superstition the notion that the most superior mind is at all infallible; it dissents without scruple from those whom it reverences most; and on the other hand the most eminent members of it encourage this freedom, are well pleased to be contradicted, and avoid assuming an oracular style as a mark of charlatanry. Such a *coup d'état* in philosophy as that of Auguste Comte is resolutely resisted, and the autocracy of Hegel comes to an end, not by the accession of a new monarch, but rather by the proclamation of a republic in German philosophy.

By the introduction of this new principle a large proportion of the doctrine current in the world is branded with the mark of spuriousness. In theology, metaphysics, moral philosophy, history, politics, the principle of authority has reigned hitherto with more or less exclusiveness. The repudiation of it is a revolution in those departments of knowledge. It converts whole libraries into waste-paper, silences controversies that have raged for ages, reduces to worthlessness the whole store of learning hived up in many capacious memories. It throws discredit at the same time upon the very name of erudition; not as such, for there is a kind of erudition much appreciated by the scientific school; but because erudition, as hitherto understood, has commonly gone along with, has in a great degree grown out of, an excessive reverence for the opinions of famous men. All that part of erudition, in particular, which is to knowledge what relic-worship is to religion, the laborious collection of minute facts that concern illustrious men, begins to seem

superstitious and childish when the general estimate of human wisdom so decidedly sinks.

But the more important change is in the extension of the Baconian method to the whole domain of philosophy. While one part of the "wisdom of the world" has been discredited as resting solely on authority, another large division of it is now rejected as resting on inductions insufficient or untrustworthy, and another as resting on groundless assumptions, disguised under the name of necessary truths, truths of the reason, truths given in consciousness, etc. The long habit of trying experiments, the vast experience which has been gained of the mistakes which may be made about matters of fact and of the infinite carelessness of the unscientific mind, have exposed to doubt whatever has been deduced in past ages from facts not recurrent or capable of being reproduced at will. The steady progress of discovery in the experimental sciences has stood out in contrast with the oscillating and unprogressive character of the sciences of mind. Moreover, in their process of extension the experimental sciences have constantly trenched on the domain which was supposed to lie definitively beyond their limit. Physiology has brought us close to mind, and the old distinction between matter and spirit begins to be slighted as a superstition. The old psychology also is assailed as not properly based on physiology. Moral philosophy does not escape. It, as well as the philosophy of law, has suffered through the influx of new knowledge about remote races of men. Duties and rights, which once appeared axiomatic, and inseparable from human nature, now appear the artificial products of special conditions. The very notion of duty itself is represented as such an artificial product.

All these new ideas gathering upon our minds produce a skepticism with regard to current philosophy which extends much further than the particular beliefs with which they seem to conflict. We have grown so accustomed to find so-called incontrovertible axioms resolve themselves into inveterate prejudices, that we have grown shy of all those facile generalities which captivated former ages. Those current abstractions which make up all the morality and all the philosophy of most people, have become suspicious and dangerous to us. Mind and matter, duties and rights, morality and expediency, honor and interest, virtue and vice, all these words, which seemed once to express elementary and certain realities, now strike us as just the words which, thrown into the scientific crucible, might dissolve at once. It is thus not merely philosophy which is discredited, but just that homely and popular wisdom by which common life is guided. This, too, it appears, instead of being the sterling product of plain experience, is the overflow of a spurious philosophy, the redundance of the uncontrolled speculations of thinkers who were unacquainted with scientific method.

This second change leads to self-distrust, as the first led to distrust of other men. As we learn not to take our truth at second-hand from other thinkers, so we learn that we must not take it, if the expression may be used, from ourselves. Truth is not what *we* think, any more than it is what famous men have thought. That which irresistibly strikes us as true, that which seems self-evident, that which commends itself to us, may nevertheless, we learn, not be true at all. It is not enough to judge for ourselves, to examine the facts independently. We must examine the facts according to a rigorous method, which has been elaborated by a long series of investigators, and without which neither candor nor impartiality would save us either from seeing wrong, or from receiving unsound evidence, or from generalizing too fast, or from allowing some delusive name to come between us and the reality. Distrust of others, distrust of ourselves—if the first of these two factors of the scientific spirit were separated from the second, the result would be mere self-conceit, mere irreverence. As it is, the scientific spirit is simply a jealous watchfulness against that tendency of human nature to read itself into the universe, which will show itself both in each individual and in the very greatest investigators, and which can only be controlled by rigorously adhering to a fixed process, and rigidly verifying the work of others by the same.

Knowledge, not scientifically obtained and verified, might very fitly be called by the name which Christianity uses. It might be called "human knowledge," or "the wisdom of the world." For the difference between it and genuine knowledge is just this, that it is adulterated by a human element. It is not the result of a contact between the universe and the naked human intelligence. The perceiving mind has mixed itself up with the thing perceived, and not merely in the way in which it always must, in the way which constitutes cognition, but in quite other and arbitrary ways, by wishes, by prejudices, by crotchets, by vanities. Such humanized views of the universe have a peculiar though cheap attractiveness. They naturally please the human mind, because, in fact, they were expressly contrived to do so. They adapt themselves readily to rhetoric and poetry, because, in fact, they *are* rhetoric and poetry in disguise. To reject them is to mortify human nature; it is an act of vigorous asceticism. It is to renounce the world as truly as the Christian does when he protests against fashionable vices. It is to reject a pleasant thing on the ground that it is insincere—that it is not, in fact, what it professes to be. The moral attitude of the man who does it is just such as Hebrew prophets assumed toward the flattering and lying court-prophets of their day; just such as Christianity itself assumed toward Pharisaism; just such as Luther and Knox assumed toward mediævalism; just such as the Puritans assumed toward prelacy. It is an attitude of indignant sincerity, an attitude marking an inward determination to face the truth of the universe, however disagreeable, and not to allow it to be adul-

terated and drugged, so as to suit our human feebleness. If we cannot produce from the authoritative documents of religion texts directly sanctioning it, this is because the particular problem was not presented in ancient times to the nation which gave us our religion. Those documents are full of passages expressing in poetic forms and in language suited to another age the spirit of modern science. Notably, the book of Job, not in occasional passages only, but as its main object and drift, contrasts the conventional, and, as it were, orthodox view of the universe, with the view which those obtain who are prepared to face its awfulness directly.

Thus the religious view and the scientific view of the universe, which are thought to be so opposite, agree in this important point. Both protest earnestly against human wisdom. Both wait for a message which is to come to them from without. Religion says, "Let man be silent, and listen when God speaks." Science says, "Let us interrogate Nature, and let us be sure that the answer we get is really Nature's, and not merely an echo of our own voice." Now, whether or not religion and science agree in what they recommend, it is evident that they agree in what they denounce. They agree in denouncing that pride of the human intellect which supposes it knows every thing, which is not passive enough in the presence of reality, but deceives itself with pompous words instead of things, and with flattering eloquence instead of sober truth.

Here, however, it will be said, the agreement between religion and science ends, and even this agreement is only apparent. Science protests against the idols or delusions of the human intellect, in order that it may substitute for them the reality of Nature; religion sacrifices all those idols to the greatest of them all, which is God. For what is God—so the argument runs—but an hypothesis, which religious men have mistaken for a demonstrated reality? And is it not precisely against such premature hypotheses that science most strenuously protests? That a Personal Will is the cause of the universe—this might stand very well as an hypothesis to work with, until facts should either confirm it, or force it to give way to another either different or at least modified. That this Personal Will is benevolent, and is shown to be so by the facts of the universe, which evince a providential care for man and other animals—this is just one of those plausibilities which passed muster before scientific method was understood—but modern science rejects it as unproved. Modern science holds that there may be design in the universe, but that to penetrate the design is, and probably always will be, beyond the power of the human understanding. That this Personal Will has on particular occasions revealed itself by breaking through the customary order of the universe, and performing what are called miracles—this is one of those legends of which histories were full, until a stricter view of evidence was introduced, and the modern critical spirit sifted thoroughly

the annals of the world. But if modern science be right in these opinions, the very notion of God is removed altogether from the domain of practical life. So long as God appeared certainly to exist, he necessarily eclipsed and reduced to insignificance all other existences. So long as it was held possible to discover his will and mind, all other inquiries might reasonably be pronounced frivolous. But all is changed as soon as we begin to regard his existence as a mere hypothesis, and his will as inscrutable and beyond the reach of the human understanding. Not only is all changed, but all is reversed. Instead of being the one important question, God's will now becomes the one *un*important question, because the one question which it is essentially impossible to answer. Whereas, before we might charge men with frivolity who neglected this inquiry for inquiries the most important in themselves, now we may pronounce the shallowest dilettant, the most laboriously idle antiquary, a solid and sensible man, compared to the theologian. They pursue, to be sure, very minute objects, but they do or may attain them; the theologian attempts an impossibility—he is like the child who tries to reach the beginning of the rainbow.

It would appear, then, that that which I have called "human wisdom," and which is the butt, at the same time, of theology and science, is so because it is a kind of middle party between two mortally hostile factions. It is like the Girondins between the Royalists and the Jacobins; both may oppose, and may even in a particular case combine to oppose it, and yet on that acconnt they may not have the smallest sympathy with each other. And the middle party once crushed, there will follow no reconciliation, but a mortal contest between the extremes. Is this so or is it otherwise? The question is whether the statement given above of the theological view of the universe is exhaustive or not? Is it all summed up in the three propositions that a Personal Will is the cause of the universe, that that Will is perfectly benevolent, that that Will has sometimes interfered by miracles with the order of the universe? If these propositions exhaust it, and science throws discredit upon all of them, evidently theology and science are irreconcilable, and the contest between them must end in the destruction of one or the other.

It may be remarked, in the first place, that these propositions are not so much an abstract of theology as of the particular theology now current. That God is perfectly benevolent is a maxim of popular Christianity, and it may be found stated in the Bible. But it is not necessary to theology as such. Many nations have believed in gods of mixed or positively malignant character. Other nations have indeed ascribed to their deities all the admirable qualities they could conceive, but benevolence was not one of these. They have believed in gods that were beautiful, powerful, immortal, happy, but not benevolent. It may even be said that the Bible and Christianity itself have not uni-

formly represented God as perfectly benevolent. In the Old Testament he is described as just, but at the same time terrible and pitiless against the wicked; and at least one form of modern Christianity, Calvinism, takes a view of the Divine character which it is impossible to reconcile with infinite benevolence. Moreover, if almost all theologies have introduced what we should ascribe as miracle, yet it would be very incorrect to class many of them in this respect with that current view of Christianity, which represents God as demonstrating his existence by occasional interruptions of the order, otherwise invariable, of Nature. Probably, in the majority of theologies, no other law of Nature, except the will of God, is recognized; miracle, when it is introduced, is not regarded as breaking through any order; the very notion conveyed by the word supernatural is unacknowledged; miraculous occurrences are not distinguished from ordinary ones, except as being rarer, and not distinguished from rare occurrences at all. To an ancient Jew probably an earthquake and the staying of the sun on Gibeon were occurrences of precisely the same character and not distinguished as they are in our minds, the one as rare but natural, the other as supernatural and miraculous. All that was miraculous might have been removed from the creed of an ancient Jew without shaking his theology. Two out of the three propositions, then, are not necessary to the theological view of the universe. But surely the third is. Surely all theology implies that a Personal Will is the cause of the universe. I cannot admit even this. In the first place it is a very shallow view of theologies which represents them as having in all cases sprung from speculation about causes. Undoubtedly we can trace this speculation in our own religion. The phenomena of the world are accounted for very manifestly in the book of Genesis by the fiat of a Personal Will. But this is not at all an invariable character of theology. The *Deity of a thing* is often regarded in theologies not at all as the cause of it, but in quite another way, perhaps I might say as the *unity* of it. No one has ever supposed that the Greeks regarded Poseidon as the *cause* of the sea. Athena seems to have been suggested to them by the sky, but she is not the *cause* of the sky. And it would be easy to conceive a theology which did not occupy itself at all with causes, but which at the same time conceived the separate phenomena of the universe, or the universe itself altogether *personally*

May we, then, alter the proposition thus—instead of saying, It is characteristic of the theological view of the universe to suppose a personal will or wills to be the cause of all phenomena, may we say, Theology invariably conceives the universe under the form of personality, a personal will being assumed as either the cause or the law of phenomena? Even this would be to go too far. Personality is only known to us as belonging to human beings. Personality is properly the abstraction of the qualities common to man, woman and child. Of these one of the principal is what we call the will.

Now, the utmost that can be said is that theology has asserted an analogy more or less strong between the phenomena of Nature and human beings. Personality entire has never been attributed in any theology to deities. Personality, as we know it, involves mortality. Deities are always supposed immortal. Personality involves a body. The highest theologies have declared God to be incorporeal. We are brought back, then, to the will. Theologies attribute to deities a *will* like that of human beings. They do so; but again the highest theologies assert that the Divine Will is high above the human; that there is "no searching" of it; "that as the heaven is high above the earth, so are his ways than our ways, and his thoughts than our thoughts."

If the possibility of miracles were entirely given up, and the order of Nature decided to be as invariable as science inclines to consider it; if all the appearances of benevolent design in the universe were explained away, it might be true that the belief in God would cease to be consoling. Instead of being a spring of life and activity, it might—I am not now saying it would—become a depressing and overwhelming influence. And this, no doubt, is what people mean when they identify, as they commonly do, the belief in God with belief in an overruling Benevolence, and in the supernatural. They mean to say, not exactly that the belief in God *is* necessarily this, but that to be in any way useful or beneficial it must necessarily be this. But for my present purpose it is important to distinguish between the God in whom ordinary people at the present day believe, and a God of another character in whom they might conceivably believe. I desire to insist upon the point that when science speaks of God as a myth or an hypothesis, and declares the existence of God to be doubtful, and destined always to remain doubtful, it is speaking of a particular conception of God, of God conceived as benevolent, as outside of Nature, as personal, as the cause of phenomena. Do these attributes of benevolence, personality, etc., exhaust the idea of God? Are they—not merely the most important, the most consoling of his attributes, but—the only ones? By denying them do we cease not merely to be orthodox Christians, but to be theists?

Science opposes to God Nature. When it denies God it denies the existence of any power beyond or superior to Nature; and it may deny at the same time any thing like a *cause* of Nature. It believes in certain laws of coexistence and sequence in phenomena, and in denying God it means to deny that any thing further can be known. God and Nature, then, express ideas which are different in an important particular. But it is evident enough that these ideas are not the opposites that controversy would represent them to be. On the contrary, they coincide up to a certain point. Those who believe in Nature may deny God, but those who believe in God believe, as a matter of course, in Nature also. The belief in God includes the belief in

Nature, as the whole includes the part. Science would represent theology as disregarding Nature, as passing over those laws which govern the universe, and occupying itself solely with occasional suspensions of them, or with ulterior, inscrutable causes. But this account of theology is derived from a partial view of it. It is practically to some extent true of the theologies of recent times, which have been driven out of the domain of Nature by the rival and victorious method of physical science. But it is not true at all of the older theologies. They occupied themselves quite as much with laws as with causes; so far from being opposed to science, they were in fact themselves science in a rudimentary form; so far from neglecting the natural for the supernatural, they recognized no such distinction. The true object of theology at the beginning was to throw light upon natural laws; it used, no doubt, a crude method, and in some cases it attempted problems which modern science calls insoluble. Then, when a new method was introduced, theology stuck obstinately to its old one, and when the new method proved itself successful, theology gradually withdrew into those domains, where as yet the old method was not threatened, and might still reign without opposition. Thus it began to be supposed that law belonged to science, and suspension of law, or miracle, to theology; that the one was concerned with Nature, and the other with that which was above Nature. Gradually the name of God began to be associated with the supernatural, and scientific men began to say they had nothing to do with God, and theologians to find something alien to them in the word Nature.

Yet theology can never go further than this in repudiating Nature. It can never deny that Nature is an ordinance of God; it can never question that the laws of Nature are laws of God. It may indeed treat them as of secondary importance; it may consider that they reveal God in an aspect in which it is not most important that we should know him. But it cannot and does not deny that Nature, too, is a revelation of God; it ought not to deny that natural philosophy is a part of theology, that there is a theology which may be called natural, and which does not consist in a collection of the evidences of benevolent design in the universe, but in a true deduction of the laws which govern the universe, whatever those laws may be, and whatever they may seem to indicate concerning the character of God.

But, if, on the one hand, the study of Nature be one part of the study of God, is it not true, on the other, that he who believes only in Nature is a theist, and has a theology? Men slide easily from the most momentous controversies into the most contemptible logomachies. If we will look at things, and not merely at words, we shall soon see that the scientific man has a theology and a God, a most impressive theology, a most awful and glorious God. I say that man believes in a God who feels himself in the presence of a Power apart from and immeasurably above his own, a Power in the contemplation of which he

is absorbed, in the knowledge of which he finds safety and happiness. And such now is Nature to the scientific man. I do not now say that it is good or satisfying to worship such a God, but I say that no class of men since the world began have ever more truly believed in a God, or more ardently, or with more conviction, worshiped him. Comparing their religion in its fresh youth to the present confused forms of Christianity, I think a by-stander would say that though Christianity had in it something far higher and deeper and more ennobling, yet the average scientific man worships just at present a more awful, and, as it were, a greater Deity than the average Christian. In so many Christians the idea of God has been degraded by childish and little-minded teaching; the Eternal and the Infinite and the All-embracing has been represented as the head of the clerical interest, as a sort of clergyman, as a sort of school-master, as a sort of philanthropist. But the scientific man *knows* him to be eternal; in astronomy, in geology, he becomes familiar with the countless millenniums of his lifetime. The scientific man strains his mind actually to realize God's infinity. In the fixed stars he traces him, "distance inexpressible by numbers that have name." Meanwhile, to the theologian, infinity and eternity are very much of empty words when applied to the object of his worship. He does not realize them in actual facts and definite computations.

But it is not merely because he realizes a stupendous Power that I call the scientific man a theist. A true theist ought to recognize his Deity as giving him the law to which his life ought to be conformed. Now, here it is that the resemblance of modern science to theology comes out most manifestly. There is no stronger conviction in this age than the conviction of the scientific man, that all happiness depends upon the knowledge of the laws of Nature, and the careful adaptation of human life to them. Of this I have spoken before. Luther and Calvin were not more jealous of the Church tradition that had obscured the true word of God in the Scriptures than the modern man of science is of the metaphysics and conventional philosophy that have beguiled men away from Nature and her laws. They want to remodel all education, all preaching, so that the laws of Nature may become known to every man, and that every one may be in a condition to find his happiness in obeying them. They chafe at the notion of men studying any thing else. They behave toward those who do not know Nature with the same sort of impatient insolence with which a Christian behaved toward the worshipers of the emperor or a Mohammedan toward idolaters. As I sympathize very partially with the Mohammedan, and not quite perfectly with the early Christian, so I find the modern scientific zeal narrow and fanatical; but I recognize that it is zeal of the same kind as theirs—that is, that, like theirs, it is theological.

An infinite Power will inspire awe and an anxious desire to obey

its laws on the part of those who feel themselves dependent on it. But such awe and fear, it may be said, do not constitute worship; worship implies admiration, and something which may be called love. Now, it is true that the scientific man cannot feel for Nature such love as a pious mind may feel for the God of Christians. The highest love is inspired by love, or by justice and goodness, and of these qualities science as yet discerns little or nothing in Nature. But a very genuine love, though of a lower kind, is felt by the contemplator of Nature. Nature, if not morally good, is infinitely interesting, infinitely beautiful. He who studies it has continually the exquisite pleasure of discerning or half discerning and divining *laws;* regularities glimmer through an appearance of confusion; analogies between phenomena of a different order suggest themselves and set the imagination in motion; the mind is haunted with the sense of a vast unity not yet discoverable or namable. There is food for contemplation which never runs short; you are gazing at an object which is always growing clearer, and yet always, in the very act of growing clearer, presenting new mysteries. And this arresting and absorbing spectacle, so fascinating by its variety, is at the same time overwhelming by its greatness; so that those who have devoted their lives to the contemplation scarcely ever fail to testify to the endless delight it gives them, and also to the overpowering awe with which from time to time it surprises them.

There is one more feeling which a worshiper should have for his Deity, a sense of personal connection, and, as it were, relationship. The last verse of a hymn of praise is very appropriately this—"for this God is *our* God forever and ever; He will be our guide even unto death." This feeling, too, the worshiper of Nature has. He cannot separate himself from that which he contemplates. Though he has the power of gazing upon it as something outside himself, yet he knows himself to be a part of it. The same laws whose operations he watches in the universe he may study in his own body. Heat and light and gravitation govern himself as they govern plants and heavenly bodies. "In him," may the worshiper of this Deity say with intimate conviction, "in him we live and move and have our being." When men whose minds are possessed with a thought like this, and whose lives are devoted to such a contemplation, say, "As for God, we know nothing of him; science knows nothing of him; it is a name belonging to an extinct system of philosophy;" I think they are playing with words. By what name they call the object of their contemplation is in itself a matter of little importance. Whether they say God, or prefer to say Nature, the important thing is that their minds are filled with the sense of a Power to all appearance infinite and eternal, a Power to which their own being is inseparably connected, in the knowledge of whose ways alone are safety and well-being, in the contemplation of which they find a beatific vision.

Well! this God is also the God of Christians. That the God of Christians is something more does not affect this fact. Nature, according to all systems of Christian theology, is God's ordinance. Whether with science you stop short at Nature, or with theology believe in a God who is the author of Nature, in either case Nature is divine, for it is either God or the work of God. This whole domain is common to science and theology. When theology says, Let us give up the wisdom of men and listen to the voice of God, and when science says, Let us give up human authority and hollow *a priori* knowledge and listen to Nature, they are agreed to the whole extent of the narrower proposition, i. e., theology ought to admit all that science says, though science admits only a part of what theology says. Theology cannot say the laws of Nature are not divine; all it can say is, they are not the most important of the divine laws. Perhaps not, but they gain an importance from the fact that they are laws upon which all can agree. Making the largest allowance for discoveries, about which science may be too confident, there remains a vast mass of natural knowledge which no one questions. This to the Christian is so much knowledge about God, and he ought to rejoice quite as much as the man of science at the rigorous method by which it has been separated from the human prejudice and hasty ingenuity, and delusive rhetoric or poetry, which might have adulterated it. By this means we have been enabled to hear a voice which is unmistakably God's. And if it seems to be God speaking about matters not of the greatest importance, still perhaps it may be as well to listen. So much, at least, reverence seems to dictate; and, if it did not, the urgent necessity for more agreement on fundamental questions would dictate it imperiously.

This train of thought will be followed a little further in future numbers of this magazine.—*Macmillan's Magazine.*

MODERN STREET-PAVEMENTS.

By ADOLF CLUSS, C. E.

THE most distinguished sanitarians of the age have established the fact that our modern cities are mostly so located that public health depends much less upon climate and position than upon rational conditions and modes of life. Enforced cleanliness, and the progress of sanitary works in cities, are followed by an enhanced vitality and elasticity of mind still more than by longevity of the inhabitants. Among sanitary works, improved pavements are classed along with sewerage, water-closets, and water-supply under pressure; since it is a prime condition of public hygiene that every

street and alley should drain as promptly and thoroughly as the houses erected on it. A proper observance of these maxims has materially contributed to the reduction of the annual death-rate of London within the last two centuries from forty-two to twenty-two per thousand, notwithstanding the unprecedented increase in the numbers and density of the population. An average decrease of thirteen per cent. in the death-rate has been traced directly to the influence of modern sanitary works, introduced into cities mostly during the last twenty years; and a thorough reform in pavements must give still more striking results.

The material for pavements is mostly decided upon by non-professional municipal authorities, and upon these an enlightened public opinion must exert a beneficial influence. A condensed review of the subject, in the light of history, technical science, hygiene, and finance, will help excite reflection, and to mature rational views, and will furnish a timely contribution to the literature of the day. Manufacturing industry, commerce, and railroads, those important motors of modern civilization, have combined to increase the number and size, and to concentrate the internal traffic of large cities, so that horses and vehicles have steadily increased, absolutely as well as in proportion to the population. Under the same influences an enormous wealth, formerly unknown, has been amassed in the cities, and whole streets have risen, lined by majestic buildings, in uninterrupted succession; while, even in the older or less pretentious streets, houses of a mere utilitarian character disappear, to make way for structures with an elevated standard of architecture. What at an earlier epoch was the proud privilege of the famous capitals of Italy, the exceptional luxury of their dwellings and mansions, is now to be found in most modern cities, though the effect be not as overpowering, on account of a want of harmony in the style.

Simultaneously with the higher wants resulting from greater wealth and closer contact, whole cities have been transformed from loose aggregates of irregularly-scattered houses into well-organized systems, all the elements of which, though serving individual purposes, are intimately connected by the complicated net-works of pipes supplying fresh water, discharging waste water and soil, and furnishing light during the night to the streets as well as to the houses, from cellar to roof; to which, perhaps, the inventive genius of the age may add, before long, the supply of heat for domestic necessities and personal comfort. In such a complex organism, the roadways and sidewalks are not merely spaces set apart for light, air, and traffic, but they are component parts of the wonderful machinery devoted to these purposes, and bear close relations to the dwellings which they separate and connect, and the restorative veins of which they cover as a protecting crust.

Of all these coöperating agencies, the least attention, until recent-

ly, was paid to the construction of roadways. Cobble-stones were resorted to for paving-purposes, since they were easily obtainable in the alluvial plains in which most modern cities are founded. They were succeeded by irregular quarried stones of such quality as was within easy reach; then by larger square blocks, mainly of trap-rock or granite, such as were thought necessary in streets with heavy traffic. But experience has proved that the jarring against them compelled the construction of heavier wagons, and that their peculiar smoothness by wear caused the horses to fall, and so this material was modified to uniform oblong blocks in narrow courses. These, after severe tests, have maintained a truer surface, have been found to offer a greater resistance against wear, to lessen the noise, and to decrease considerably the number of accidents to horses. They are called, in common with the former, *Belgian* blocks.

A most important sanitary feature, almost entirely neglected before the rapid concentration of population in the cities, now demanded attention. The cubical stone blocks are displaced under the prodigious traffic, the corners and edges are worn away, the surface gets to be irregular, the joints are widened. The filth of the streets gathers in ruts and joints, is recruited constantly by new accessions of urine, horse-dung, and silt, and, diluted by the rain, it ferments, and forms a putrescent organic mire, becoming in course of time a source of noxious miasmas. In hot and dry weather these nauseating deposits pass into the atmosphere in the form of unhealthy vapors, or, pulverized and drifted by the wind, cause inconvenience and poison our lungs. Indeed, in repairing old pavements, a black layer of ground, saturated with sulphuretted hydrogen, is found below the stone blocks, and bears witness to the infection of the subsoil by the soakage of contaminated water. Prof. Tyndall has established by experiments that a large proportion of the particles of dust in the rooms of London houses is of organic origin, and other experiments have demonstrated that horse-manure, in a state of decomposition, is a permanent ingredient.

Vapors still more noxious than those from the road-bed of the streets rise from the gutters, the subsoil of which is saturated to a considerable depth by more concentrated matter of the described composition, and also from the surface of alleys on which are the houses of great numbers of people of limited means. Crowds of dirty children, whose tender lungs breathe the air immediately over this miasmatic soil, here contract constitutional predispositions, which doom them to a languishing and miserable life, and render them an easy prey to epidemics. This infection of the subsoil has been prevented, with a certain degree of success, by foundations of concrete. There is still another feature of stone pavements in the heart of cities, which affects the inner man more than the physical frame, viz., the rattling and noise, under heavy traffic, accompanied, in alluvial soil, by vibrations

of the adjoining buildings. People with strong nerves, and accustomed to this rattle from early youth, may to some extent become hardened, but they will never get to be insensible to it; any indisposition is aggravated by the nuisance, and for recovery they hurry to the country. People with weak nerves, especially delicately-organized women, suffer great and permanent injury to the health. Nothing but the constant torment has partially dulled us to this evil. If cities had never been afflicted with this noise, and if, in a competition with other more suitable materials, stone pavements were adopted, a storm of opposition would soon sweep them out of existence again. Some of these difficulties have been obviated by using smaller and harder stones; but the objection to the improved Belgian pavement in general use, on account of the germs of disease stored in the wide joints and under the blocks, still remains.

To do away with the objection to stone pavements, efforts were made to introduce into cities the macadamized roads, which had proved eminently successful as country roads; these efforts have proved signal failures, though, when properly made, and in thoroughly good order, macadamized roads approach perhaps more nearly the desiderata than most others that have been tested, and are among the pleasantest and safest roadways in ordinary use. But the constant outlay for repairs, the difficulty of traction over them when recently laid, and considerations of hygiene and comfort, are such serious objections that they are gradually being displaced by other kinds of pavement. Whoever is doomed to live on a macadamized street needs no description of its horrors. These streets have justly been nicknamed crushing-mills for granite. Six hundred and fifty thousand tons of granite are annually pulverized on the streets of London, of which but one-sixth is due to the wear of paving-stones, the rest is attributable to the macadamized roads. This dust has to be scrubbed, washed, and brushed ever so often from clothes, furniture, stairs, and floors, before it is finally removed through silt-basins and carts, or sewers and river.

A little rain transforms these streets into broad slush-beds from which every thing within reach is bespattered by the hurrying wheels of vehicles. Ladies with modern garments cannot cross them, and whoever visits along such streets must leave a certain quantity of dirt on floors and carpets. But mud is not the worst affliction, for this mash, consisting of stone-dust, sand, and horse-dung, is transformed into dust by dry and hot weather, is whirled up by the rolling wheels, or, still worse, is drifted by wind, rendering the air unfit for respiration, penetrating into the tender, sensitive cavities of the lungs, settling on skin, hair, and clothes; suffocating the flowers and green leaves of plants along parked streets; forbidding the opening of windows, fouling the glass, and driving through the joints of the sash; lodging in curtains and blinds, spoiling the costly products of industry and man-

ufacture in the show-windows, and haunting the anxious housewife in kitchen, pantry, and cellar. The devoted denizen finds but a partial protection against the shocking nuisance, when he mixes this dust with an abundance of water—by sprinkling the street.

A modification of the macadam is the *Telford road;* it consists of a bed of firmly-wedged quarry-stones, with an even surface as a foundation, upon which a layer of larger and a layer of smaller broken stone, mostly trap-rock, are spread, each being rolled by horse and steam rollers. Upon the well-compacted surface a binding of screened gravel is applied, moistened and rolled in, so as to present one solid mass, which, while hard and durable, yet retains some elasticity. This variety, superior for country-roads, though still open to the vital objection of dust, is equal in price to the costly modern city pavements, and therefore has found but a limited application within city limits—for instance, on the Boulevards of New York.

Wood pavements which, at one time, were much used in Britain, especially in London, and also in New York in 1835 and 1836, but were abandoned for weighty reasons, and especially on account of their rapid decay, were revived in the rising cities of the great West, notably Chicago, where stone was scarce, lumber was cheap, and a porous, sandy subsoil retarded the decay of the perishable wood-blocks by dry rot from below, as happens on retentive soil. These wood pavements, smooth, noiseless, and advantageous for traction, were rather hastily adopted by municipal committees or boards in Eastern cities, where the conditions were different, and where decomposition commenced after two or three years' use. The heavy profits made induced a desperate fight in their favor by interested parties, a renewed effort in behalf of "treated" wood gave them a respite and a second harvest before final disuse, which was accelerated, however, by the overwhelming complaints of the offensive and unhealthy effluvia emitted from them; so that, in a sanitary point of view, the advantage of the absence of stone-dust was much overbalanced by the decomposition of the material itself.

The wood-blocks during treatment have been mostly impregnated, by pneumatic processes, with chloride of zinc, sulphate of iron, or oily, creosotic substances; and, though railroad-sleepers, telegraph-poles, etc., have been satisfactorily preserved through these agencies, such methods have failed, for various causes, to render an equivalent for the expenses incurred in treating the paving-blocks. But the patience of the people is not yet exhausted, and, in Northwestern cities, a new and costly revival is being arranged by the substitution of sulphate of copper for impregnation, a substance used in France, under M. Boucherie's patent, for thirty-five years past. The District of Columbia has been preëminently the experimental ground for treated wood pavements. An investment of about $5,000,000, a sum far in excess of that in any other city of the globe, has been made there within

little more than three years in wood pavements, nearly all treated; many of them are now in an advanced state of decay, and, from the degree of preservation after two or three years' use on suburban streets with hardly any wear, one cannot approve of any of the processes applied, since none of them have effectively neutralized the destructive local agencies, or made up for inferiority in the quality of lumber used. Square, polygonal, wedge-shaped, and undressed round blocks, of pine, spruce, and juniper wood, set in rows, interlocking or parted by interstices, upon sand, board, or concrete foundations, were tried, so that all classes of patentees had chances to trot out their hobbies and gratify their passion to serve the community. Though this is an interesting study, we cannot in this place do full justice by entering into details.

The idea of ranking expensive wood pavements, treated and untreated, as valuable standard pavements, where more substantial materials can be procured at the same or lower prices, will, before long, hardly more than elicit a smile from the critical expert.

In this state of the problem, it may be considered as a new epoch in city-life that the increased facilities of commercial intercourse, by cheapening the cost of transportation, have brought a relief within reach, namely, asphaltum for roadways. The nature of asphaltum is frequently misunderstood, because the mineralogist, in speaking of asphaltum, has reference to the brittle bitumen usually found in Nature, while the civil-engineer designates by mineral asphaltum a porous limestone, in combination with tough bitumen. This limestone was primarily impregnated by volcanic action with petroleum, which appears to have oxidized within the structure of the stone by the slow action of many centuries. Thus both ingredients have been united so thoroughly in the asphaltum that neither heat nor water, nor the combined action of both, in causing decay, can render it hard and brittle by abstracting the tough bitumen from the limestone. It is not strange that the efforts artificially to imitate this intimate union have often produced materials with quite different powers of resistance against the various destructive agencies and vicissitudes of climates; and that the lack of durability—not to speak of numerous dead failures in various compounds of raw or treated coal-tar and coal-pitch with coal-ashes, saw-dust, cinders, sand, gravel, etc., commonly called concrete pavements, which have reduced moderately dirty streets, under the influence of the heat of summer, to vast sticky quagmires—has formed a serious drawback to the introduction of better material, and especially the well-tested native asphaltum, which will probably, in our climate, many times outlast the best artificial composition yet known, as it has done in other countries. The admixtures and distillations from coal-tar and pitch have been amply relied upon as the base for artificial concrete, on account of a supposed resemblance to the native asphaltum. This idea, however, is

not sustained by modern scientific tests. Seen in thin layers under the microscope, the bitumen, the color of which is otherwise a deep black, shows a transparent yellowish mass, while coal-pitch is visible as a mass of coherent black points on an orange-colored ground. This investigation of the mastic relied upon suffices to explain in the one case the quality of toughness and binding power, and in the other that of brittleness.

Efforts are now being made to produce concrete pavements based on mixtures of silicate of soda with Portland cement. The latter, along with native asphaltum, is undoubtedly the most important modern building-material, but it has its separate province, and lacks just those qualities of the native asphaltum which are so highly appreciated for paving-purposes. It will hardly ever be successful in the long-run when encroaching on the sphere of the competing material which it has fairly outrivaled as a cement for brickwork and masonry, for which, in ancient times, asphaltum enjoyed a just celebrity, as attested by the remnants of the walls of Babylon and Nineveh. This class of pavement has been tested carefully in France with the well-known *béton coignet* and has failed. While the artificial mixtures soon require expensive surfacing, the native asphaltum when taken up for piping, or otherwise, after many years' wear, may be used again by simply heating and treating it as at first. In this aspect it bears such a relation to the artificial concretes as a copper roof does to a common tin roof.

Nature has unfortunately produced this valuable mineral deposit in but very few cases, and it has not yet been found in America, for the so-called Trinidad asphaltum consists mainly of bituminous scoriæ, cemented together with vitrified sand and earth; and even the more esteemed Cuban asphalts contain from 27 to 34 per cent. of earthy substances. The deposits from Tyrimont-Seyssel, on the banks of the Rhone, in France, were the first to be used for pavements. But, as they contain only from 6 to 8 per cent. of bitumen, the powdered rock was found rather too dry, and therefore was superseded by the extensive deposits of the Val de Travers, the most important valley debouching from the Jurassic mountains of Switzerland into the Lake of Neufchâtel. These, with steady march, have conquered the markets of the world. The deposits known as Neufchâtel rock contain, with a constancy not found anywhere else, from 11 to 12 per cent. of bitumen—a most favorable proportion. Besides, they have absolutely greater toughness as a result of their degree of oxidation. They were formerly extensively used as a mastic for sidewalks, and form an excellent material for carriage-ways. They have been used since 1854 in Paris, and since 1868 in the principal thoroughfares of London and other European capitals.

The success of this bituminous rock pavement is by no means due to the lucky hit of one individual; it is the legitimate result of

the persistent efforts of some of the best engineers of the age, by which all obstacles have been gradually overcome. The first trials were made with mastic, consisting of the powdered rock melted with mineral tar as a flux, and mixed with sea-grit which was laid upon an ordinary concrete foundation; they were followed by experiments with mastic, cast into blocks at the workshops, and laid with wide joints, which were filled in again with heated mastic. Next we hear of tests with broken asphaltic rock, rammed in a cold state upon a macadam foundation. And finally these intelligent labors were crowned by the splendid improvement of the compressed rock pavement, for which the rock, reduced by heat to powder and rammed and rolled while yet hot, into a homogeneous, tight covering, is laid upon a perfectly dry ordinary concrete foundation composed of crushed stone and cement. This simple improvement virtually adapts the old principle of a barn-floor of rammed clay, for thrashing, to the requirements of the open air, by making it water-proof. In place of the mastic, which attains consistency, by the congelation of the melted mass, without application of pressure, this "merely compressed body, in which the molecules of bitumen and limestone are soldered together by heat and ramming," obviates all tendency toward brittleness, without in the least interfering with the advantages of perfect homogeneity or water-proof qualities. It stands to reason that the mastic, which, notwithstanding its mixture with grit, is more or less pitchy, would be surpassed in elasticity and pliability by a merely kneaded mass. These pavements are reported to have withstood the extreme heat of Bombay, Hindostan, as well as the greatest known cold. Not affording any escape to the terrestrial heat through joints, they are kept warm and open from below in most cases when block-pavements present an icy surface. Their smooth, seamless face, being almost entirely free from abrasion by attrition or atmospheric action, meets the mechanical and hygienic objections to block-pavements, both of stone and wood, as well as of macadamized roads.

The asphaltum pavement is clean and fit for traffic a few hours after being laid, while new or repaved stone roadways must be covered for months with heavy layers of sand, to be drifted by the breeze in dry weather and added to the mud in rainy spells. Repairs can be made to the asphaltum pavement in dry days of a cold winter, while with stone pavements any defects must be endured until spring. Besides the sanitary advantages, the saving in temper, clothes, shoes, and furniture, is not to be overlooked. The popularity of this pavement in the two largest cities of Europe, where, with immense traffic and most extensive experience on the relative value of pavements, the demands on the municipal authorities are inexorable, serves as a proof that smoothness of surface does not cause any danger with this material. Being elastic but not soft in summer, and hard but not brittle in winter, it possesses with a slight yield the power of readjustment in

a high degree, so that horses and drivers ever seek it, if it is "laid intelligently by practised hands, with a low crown" or flat profile.

A low crown is practicable because there are no surface-obstacles to drainage. It is also needful to prevent horses from falling on any spaces with a heavy decline toward the gutter. What is essential for the transverse profile of these streets is no less essential for their longitudinal profile: they must have easy grades—say a pitch of less than two per cent.—since the momentum of inertia of the masses in motion enters the problem. The smooth surface intensifies the downward motion of the wheels while decreasing the friction of the hoofs of the horse, which furnishes the power of resistance against the downward motion of the vehicle, or serves for affixing the power necessary to move the vehicle up-hill. With these precautions relief is afforded to the horse, this faithful companion of man, which, being dumb, is so often brutally ill-treated and abused.

It would lead too far to enlarge upon the numerous official experiments and observations made in Paris and London by which, though made under circumstances most unfavorable for the new pavements, the proportion of accidents to horses and vehicles has been shown to be considerably less on the asphalt than on stone pavements, except in the rare case of a muddy street during wet weather. Ordinary care can achieve much in that direction. When driving on to an isolated asphaltum road, to which, in wet weather, mud has been dragged from adjoining streets of old construction, the change ought to be managed by checking the horses and gradually returning to full speed. As, by degrees, the regeneration of the streets becomes general, this temporary precaution will become unnecessary. Allusion to these minor details was deemed *à propos*, since the human mind is so constituted that little is generally thought of accidents of daily occurrence, while we are apt to be severe and even unjust against novel improvements, which, of course, in the beginning present more or less difficulties to be overcome under actual tests. The same man who unconcernedly sees a horse fall on a stone-paved street, or blames the driver, and even the horse itself, regardless of the pavement, might be loud with complaints or fears about the falling of a horse if traveling on a road of new construction.

During the careful examinations as to the merits of the new pavement, questions were raised regarding its fire-proof qualities. Indeed, we hear that, during the siege of Paris by the Germans, the population, visited by cold, and short of fuel, tore up the asphaltum roads to enjoy fires fed therewith. But, on the other hand, it is also recorded that, during the eventful time of the Commune, when incendiarism was frequent and ingenious, these pavements never caught or spread the fire, the proportion of the combustibles to the incombustibles in the asphaltum of the streets being too small to feed the fire. The matter-of-fact people of London were not satisfied with any thing

less than severe direct tests: their engineers had to pile wood upon the asphaltum pavement, pour petroleum over it, and light it. When the fire burned most lively, and there were plenty of red-hot coals underneath, the space was cleared and nothing but little flames were noticed, which immediately died out. G. A. Shaw, the head of the London fire-brigade, who attended, declared expressly his faith in the harmless nature of the pavements during conflagrations. There is no doubt that asphaltum pavements may occasionally fail, but, when they do, this is attributable not to the material, if unadulterated, but rather to the method of its application, which requires skilled workmen, whose eyes and hands are quick and directed by an intelligent mind. The District of Columbia has about $1,750,000 invested in concrete and asphalt pavements, including the various patented mixtures and the natural asphaltic rock, and, though a certain degree of success has been attained under some of the patents, this does not appear to be uniform and under control of the engineers; nearly all show clear evidences of disintegration, and are periodically in need of repairs or resurfacing, which latter means virtually a failure of the patented process, while the pavements of natural rock rather improve by wear, and their first cost, in depreciated securities, was but $4.25 per square yard against $3.20 for the patented admixtures.

After these explanations, based on personal observations, as well as on the results of the experience of the leading engineers in this branch, the conclusion may well be drawn that asphaltum roads are destined to be the city pavements of the future—a destiny which is determined by the progressive spirit of the age, and which cannot be retarded for any length of time; it involves the interests of all, both high and low. If the most elegant and most frequented streets have the privilege to lead the van, it ought to be appreciated that the luxurious life of the higher classes depends upon the strength and activity of the children of the industrious classes as much as upon the toil of the farm-hand who, fortunately enough, is enabled to recruit his strength in open fields; hence, justice should be done likewise to the demands of health for the poorer classes, who, in consequence of the highly improper laying out of the cities, as bequests of by-gone generations, are frequently doomed to live in alleys and lanes, and these should be drawn into the vortex of a reform which, when accomplished, will gladden the humanitarian, whose head and heart are in sympathy with civilization in its noblest aspect.

WASHINGTON, *March* 26, 1875.

DISCOURSE ON THE DEATH OF LYELL.

By Dean STANLEY.

DEAN STANLEY selected for his sermon the words of the second verse of the first chapter of Genesis: "The earth was without form, and void; and darkness was upon the face of the deep. And the spirit of God moved upon the face of the waters." The sermon was, in fact, a discourse on the religious aspect of geology.

The words of the text, the dean said, have a sense wider than the mere literal transcript. They express the transition from that gulf which the Greeks called chaos, to the order of the universe which a modern philosopher described under the head of "cosmos." The words in the original, which portray the formless void of the earth, convey most precisely the image of warring elements, while the words used for the moving of the Divine Spirit on the face of the waters express the gentle brooding, as it were, of a bird of peace. The language, however poetic, childlike, parabolical, and unscientific, impresses upon us the principle which applies, in both the moral and in the material world, that the law of the divine operation is the gradual, peaceful, progressive development of discord into harmony, confusion into order, darkness into light.

It chanced that within the short month of February, by a most unusual coincidence of mortality, twice had the gates of the abbey been opened to pay the last honors to two men widely apart in all else, but alike in the share they took in unfolding and exemplifying this divine law, the one the acknowledged chief of the English musicians of our time, the other the acknowledged head of those who, whether here or elsewhere, have devoted their talents to the study of the history of our mother earth. Of all the branches of art and letters, none more reveals the hidden capacities of the human soul, or the fearful and wonderful structure of the human frame, than the slow process through which, from the most barbarous sounds, the spirit which brooded over the harp of David, and inspired the genius of Beethoven and Mendelssohn, has gained its majesty and glory.

This passing allusion to a great musician, this indication of the latent capacities for spiritual emotion brought out by abstract and inanimate things, elements seemingly without form and void, was no unfitting prelude to the consideration of the study of Nature, of which he who has just gone was so bright an example.

It is well known that, when the study of geology first arose, it was involved in interminable schemes of reconciliation with the letter of Scripture. There were and are two modes of reconciliation, which have each totally and deservedly failed. The one attempts to wrest the words of the Bible from their real meaning, and force them to

speak the language of science; and the other attempts to falsify science to meet the supposed requirements of the Bible. The "seventy," finding that the hare was described as chewing the cud, inserted the word "not;" and on the other hand, the Jesuits, in editing Newton's "Principia," announced in the preface that they were constrained to treat the theory of gravitation as a fictitious hypothesis, else it would conflict with the decrees of the popes against the motion of the earth.

But there is another reconciliation of a higher kind, or rather not a reconciliation, but an acknowledgment of the affinity and identity which exist between the spirit of science and the spirit of the Bible. First, there is a likeness of the general spirit of the Bible truths; and, secondly, there is a likeness in the methods. For instance, the geological truth which our illustrious student was the chief instrument in clearly setting forth and establishing was the doctrine, wrought out by careful, cautious inquiry in all parts of the world, that the frame of this earth was gradually brought into its present condition not by sudden and violent convulsions, but by the slow and silent action of the same causes which we see now, but operating through a long succession of ages beyond the memory and imagination of man. There need be no question whether this doctrine agrees or not with the letter of the Bible. We do not expect it should. For, had there been no such scientific conclusions, we now know perfectly well, from our increased insight into the nature and origin of the early biblical records, that they were not and could not be literal, prosaic, matter-of-fact descriptions of the beginning of the world, of which, as of its end, no man knoweth or can conceive except by figures or parables. It is now clear to all students of the Bible that the first and second chapters of Genesis contain two narratives of the creation side by side, differing from each other in almost every particular of time and place and order. It is now known that the vast epochs demanded by scientific observation are incompatible both with the 6,000 years of the Mosaic chronology and the six days of the Mosaic Creation. No one now infers from the Bible that the earth is fixed, that it cannot be moved, that the sun does literally go forth as a bridegroom from his chamber, or that the stars sung with an audible voice in the dawn of the creation. But when we rise to the spirit, the ideal, the general drift and purpose of the biblical accounts, we find ourselves in an atmosphere of moral elevation which meets the highest requirements philosophy can make.

The discoveries of geology are found to fill up the old religious truths with a new life, and to derive from them in turn a hallowing glory. When the historian of our planet points out that the successive layers of the earth's surface were formed by such agencies as we know of now, by the constant action of wind and wave, of floating ice and rolling stones—that there were not separate centres of creation, but one primeval law which formed and governed all created things—what is this but the echo of those voices which of old de-

clared that in the beginning the heaven and earth were created, not by a thousand conflicting deities, but by one supreme and indivisible, and that He hath given all things a law that shall not be broken? And we may compare the vast infinities of time and space, that long ascending order, that gradual progress demanded by geology, with the words in the sublime ninetieth psalm, read at the burial service: "A thousand years in thy sight are but as yesterday which is past, and as a watch in the night." Surely the view of the gradual preparation of the earth for mankind is grander than that which makes him coeval with the beasts which perish, and we ought to honor the archæologist who by unhasting, unresting research revealed in all their length and breadth the genealogy and the antiquity of man and of his habitation. He rent the veil and showed the long vista of the temple of the Most High, not made with hands—"*Apparet domus intus, et atria longa patescunt.*" Not the limitation but the amplification of the idea of God is the result of the labor of such a student, and not the descent but the ascent of man is the outcome of his speculations. If, as he used to say, we have in our bones the chill of the contracted view of the past in which till now we were brought up, the enlargement which he effected of that view ought to give a warmth, a fire to our soul of souls, in proportion as we feel that we are indeed not the creatures of yesterday, but the heirs of the ages and worlds that have perished in the making of us.

As to the likeness of the general spirit of the method of science to that of the Bible, the Bible is a model to the student in its slow but increasing purpose of revelation, through sundry times and divers manners, warning each succeeding age to have its eyes open and every member of the human race to be the disciple—that is, "scholar," as the founder of Christianity called his followers. To invest the pursuit of truth with the sanctity of a religious duty is the true reconciliation of religion and science. Such a union has been the special glory of the great school of English geologists, and the two pioneers of the science at the time when it had to fight its way against prejudice, ignorance, and apathy, were both honored dignitaries of the English Church; and now within these walls there rests beneath the monument of Woodward one who was the friend of Sedgwick and the pupil of Buckland. He followed truth with a sanctified zeal, a childlike humility. For discovering, confirming, rectifying his conclusions, there was no journey he would not undertake. From early youth to extreme old age it was to him a religious duty fearlessly to correct all his own mistakes, and he was always ready to receive from others and reproduce that which he had not in himself. In his mind science and religion were indivisible. The freedom of religious inquiry in the national Church, the cause of humanity in the world at large, were to him as dear as though they were his own personal and peculiar concern. There is unusual solemnity in the thought of his passage into the eternal world, on which, as in a shadow or

mirror, he had so long meditated, in those long ages of which he was, as it were, the first discoverer. The "lofty and melancholy strain," the ninetieth Psalm, which old tradition ascribes to Moses, the man of God, whether it be or not the funeral hymn of the great lawgiver, well represents the feeling of one grown gray with vast experience, who at the close of his earthly journeyings contrasts the fleeting generations of man with the granite forms of the mountains at the feet of which he has wandered, and contrasts those mountains and man alike with Him who existed before, beyond, and above them all. It sums up with peculiar force the inner life of the Christian philosopher who concluded his chief work with the contrast between the finite powers of man and the attributes of an infinite God, and who felt persuaded that, after all the discoveries on earth or sea or sky, the religious sentiment remained the greatest and most indestructible instinct of the human race.

THE PHYSIOLOGY OF AUTHORSHIP.

By R. E. FRANCILLON.

THERE is a botanical theory that a flower is nothing more than a leaf in which full development has been arrested. It is more beautiful than the leaf by reason, not of its perfection, but of its imperfection. Even so the leaf is a degenerate twig and the fruit a degenerate flower: so that productiveness comes from the loss of vital strength, and not, as would be assumed at first sight, from its increase. This is not, I believe, the orthodox scientific doctrine, but it is plausible enough to suggest an analogy. The history of a plant, according to the theory of degeneration, is strikingly like the pedigree of literary and artistic genius, according to any of the hundred definitions of that indefinite word. So far as known facts combine into a probable law, a creative intellect is never generated spontaneously. Like dukes and princes, men of imaginative genius have ancestors between themselves and Adam. *Bon chat chasse de race.* The lives of the mothers of great men form an important branch of biographical literature: and it is usual, even in the paternal line, to find traces of hereditary taste or talent tending toward original production. The mute, inglorious Milton finds a glorious tongue in his great-grandson: the great statesman is the heir of the village Hampden. The theory, though more than merely probable, is by its nature incapable of exhaustive proof: but instances are notorious enough to found thereon a reasonable assumption that family talent precedes individual genius even if the tendency has never made itself conspicuous, or, like the gout, has passed over a generation or two here and there. But, on the other hand, it is yet more certain that genius, like

the blossom with its fruit, closes while it crowns the family tree. The man of talent is the ancestor of the man of genius, but the man of genius is the ancestor either of nobodies or of nobody. Descendants of great authors, painters, and musicians, who lived two or three generations ago, are hardly to be found. While the families of great soldiers and statesmen swarm, there is scarcely a man in Europe who can boast of a great poet or other artist in the direct line of his pedigree: probably there is not even one who can boast of two such forefathers. The rough stem runs into the leaf, the leaf to the flower, and the flower to the fruit of good work, or—to seed. To pursue the analogy to its end, the full beauty and productiveness of imaginative genius correspond to the effect of decaying vitality.

Analogy, built upon an unscientific metaphor, is of course no argument: but it is a fair explanatory illustration of a theory that rests upon surer ground for its foundation. That the creative imagination or any other mental gift so far resembles disease as to require non-natural conditions for its exercise is not the popular doctrine. The well-known and often-quoted couplet about the near alliance of great wit to madness is directly opposed to the far more pleasant belief in sound minds in sound bodies as the most favorable condition for the production of the best work of all kinds. The tone of hero-worshipers themselves is, to deplore eccentric indulgences as weaknesses of genius rather than to recognize in them the artificial atmosphere necessary for production and creation. The popular doctrine is thoroughly wholesome, because it is taught by the many for the many, and to teach otherwise, in a broad way, would risk the popular confusion of genius with its accidents. But all safe, wholesome, popular doctrines have an unfortunate tendency to turn men at large into a great flock of sheep—infinitely better worth owning than a herd of red deer, but proportionately less full of individual character. The history of how imaginative work is done reads very like a deliberate and apparently insane effort to keep up the action of brain-fever by artificial stimulus, as if creative genius were literally an unsound habit of mind requiring an unsound habit of body—*mens insana in corpore insano*. Balzac, who had the disease of creative genius in its most outrageous form, "preached to us," says Théophile Gautier, "the strangest hygiene ever propounded among laymen. If we desired to hand our names down to posterity as authors, it was indispensable that we should immure ourselves absolutely for two or three years: that we should drink nothing but water and only eat soaked beans, like Protogenes: that we should go to bed at sunset and rise at midnight, to work hard till morning: that we should spend the whole day in revising, amending, extending, pruning, perfecting, and polishing our night's work, in correcting proofs or taking notes, or in other necessary study." If the author happened to be in love, he was only to see the lady of his heart for one half-hour a year: but he

might write to her for the cold-blooded reason that letter-writing improves the style. Not only did Balzac preach this austere doctrine, but he practised it as nearly as he could without ceasing altogether to be a man and a Frenchman. Léon Gozlan's account of the daily life of the author of the "Comédie Humaine" has often been quoted. He began his day with dinner at six in the afternoon, at which, while he fed his friends generously, he himself ate little besides fruit and drank nothing but water. At seven o'clock he wished his friends good-night and went to bed. At midnight he rose and worked—till dinner-time the next day: and so the world went round. George Sand calls him, "Drunk on water, intemperate in work, and sober in all other passions." Jules Janin asks, "Where has M. de Balzac gained his knowledge of woman—he, the anchorite?" Love and death came to him hand-in-hand: so that he might be taken as an example of the extreme result of imaginative work obtained by the extreme avoidance of artificial stimulus, and therefore as a fatal exception to the general theory, were it not for one little habit of his which, though a trifle in itself, is enough to bring his genius within the pale of the law. When he sat down to his desk, his servant, who regarded a man that abstained even from tobacco as scarcely human, used to place coffee within reach, and upon this he worked till his full brain would drive his starved and almost sleepless body into such self-forgetfulness that he often found himself at daybreak bareheaded and in dressing-gown and slippers in the Place du Carrousel, not knowing how he came there, and miles away from home. Now, coffee acts upon some temperaments like laudanum upon others, and many of the manners and customs of Balzac were those of a confirmed opium-eater. He had the same strange illusions, the same extravagant ideas, the same incapacity for distinguishing, with regard to outward things, between the possible and the impossible, the false and the true. His midnight wanderings, his facility for projecting himself into personalities utterly unlike his own, belong to the experiences of the "English Opium-Eater." On this assumption, the exaggerated abstinence of Balzac is less like an attempt to free the soul from the fetters of the flesh than a preparation for the fuller effect of a stimulus that instinctive experience had recommended. In any case his intemperate temperance is the reverse of the conditions in which wholesome unimaginative work can possibly be carried on.

Byron affords a similar, though of course less consistent, illustration of a tendency to put himself out of working condition in order to work the better. "At Disdati," says Moore, "his life was passed in the same regular round of habits into which he naturally fell." These habits included very late hours and semi-starvation, assisted by smoking cigars and chewing tobacco, and by green tea in the evening without milk or sugar. Like Balzac, he avoided meat and wine, and so gave less natural brain-food room for more active play. Schiller

was a night-worker and a coffee-drinker, and used to work on champagne. Not only so, but he used an artificial stimulus altogether peculiar to himself: he found it impossible, according to the well-known anecdote, to work except in a room filled with the scent of rotten apples, which he kept in a drawer of his writing-table, in order to keep up his necessary mental atmosphere. Shelley's practice of continually munching bread while composing is not a mere piece of trivial gossip when taken in connection with more striking and intelligible attempts to ruin the digestion by way of exciting the brain, and when it is remembered that his delicate and almost feminine organization might require far less to throw it off the balance than naturally stronger frames. At all events, it seems to point to the same instinctive craving for abnormal aids to work when the imagination is called upon—as if it were not intended that the creative power should be a function of the natural man. Of course there is no need to suppose that the stimulus is always or even often adopted with the deliberation of the actor, who used to sup on underdone pork-chops to inspire himself with the mood proper to tragedy. Nor need the stimulus be of a kind to produce intoxication, in the vulgar sense of the word. So long as it puts the body into a non-natural condition, in the way pointed out by individual instinct, it seems that the physical conditions of imaginative work are fulfilled.

Unfortunately for any complete treatment of the question, a sufficient body of data is not easily gathered. Great artists, in all fields of work, are notoriously shy of publishing their processes, even when they themselves know what their processes are. It is, however, always legitimate to argue from the known to the probable; and if it can be gathered that all great imaginative work, whenever the process is known, has been accompanied with some abnormal habit, however slight, it is fair enough to assume that the relation of cause and effect has something to do with the matter, and that some such habit may be suspected where processes are not known. There are, however, two great imaginative authors of the very first rank whom believers in the pleasant doctrine that the highest and freest work can be done under the healthiest conditions of fresh air, early hours, daylight, and temperance—which does not mean abstinence—have always claimed for their own. One of these is Goethe. He and Balzac are at precisely opposite poles in their way of working. Here is the account of Goethe's days at Weimar, according to Mr. G. H. Lewes: He rose at seven. Till eleven he worked without interruption. A cup of chocolate was then brought, and he worked on again till one. At two he dined. "His appetite was immense. Even on the days when he complained of not being hungry he ate much more than most men. . . . He sat a long while over his wine, chatting gayly, for he never dined alone. . . . He was fond of wine, and drank daily his two or three bottles." There was no dessert—Balzac's principal meal—nor

coffee. Then he went to the theatre, where a glass of punch was brought him at six, or else he received friends at home. By ten o'clock he was in bed, where he slept soundly. "Like Thorwaldsen, he had a talent for sleeping." No man of business or dictionary-maker could make a more healthy arrangement of his hours. The five or six hours of regular morning work, which left the rest of the day open for society and recreation, the early habits, the full allowance of sleep, and the rational use of food, are in glaring contrast to Balzac's short and broken slumbers, his night-work, and his bodily starvation. But he who imagined "Faust" is not to be so easily let off from his share in illustrating a rule. There is no need to quarrel with Mr. Lewes for going out of his way to prove that Goethe was not necessarily a toper because he liked wine and had a good head. Though a great deal of wine was no doubt essential to his general working power, it was in his case rather a tonic than an immediate stimulant, because it came after instead of during work-hours. But this is significant of the same result, only in a different way. Goethe differed from almost every great poet in not doing his greatest work at a white heat; and not only so, but he differed also in constantly balancing his reasoning against his creative faculties. I doubt very much if those long mornings of early work were often spent in the fever of creation. He was a physiologist, a botanist, a critic; and the longer he lived he became more and more of a *savant*, if not less and less of a poet. His imagination was most fertile before he settled down into these regular ways, but not before he settled down into a full appreciation of wine. Balzac would write the draft of a whole novel at a sitting, and then develop it on the margins of proofs, revises, and re-revises. Goethe acted as if, while art is long, life were long also. Till the contrary is proved, I must consistently hold that Goethe was the philosopher before dinnert-ime, and the poet in the theatre, or during those long after-dinner-hours, over his two or three bottles of wine. That these later hours were often spent socially proves nothing one way or the other. Some men need such active influences as their form of mental stimulus. Alfieri found or made his ideas while listening to music or galloping on horseback. Instances are common in every-day life of men who cannot think to good purpose when shut up in a room with a pen, and who find their best inspiration in wandering about the streets and hearing what they want in the rattle of cabs and the seething of life around them, like the scholar of Padua, whose conditions of work are given by Montaigne as a curiosity. "I lately found one of the most learned men in France . . . studying in the corner of a room, cut off by a screen, surrounded by a lot of riotous servants. He told me—and Seneca says much the same himself—that he worked all the better for this uproar, as though, overpowered by noise, he was obliged to withdraw all the more closely into himself for contemplation, while the storm of voices drove his thoughts inward. When at Padua he

had lodged so long over the clattering of the traffic and the tumult of the streets, that he had been trained not only to be indifferent to noise, but even to require it for the prosecution of his studies." So we learn from Mr. Forster that "method in every thing was Dickens's peculiarity, and between breakfast and luncheon, with rare exceptions, was his time of work. But his daily walks were less of rule than of enjoyment and necessity. In the midst of his writing they were indispensable, and especially, as it has often been shown, at night." When he had work on hand he walked all over the town, furiously and in all weathers, to the injury of his health. And his walks, be it observed, were frequently what Balzac's always were—at night; so that in the matter of hours he must be taken as having conformed in some important respects to Balzac's hygiene. Now, Goethe was also an essentially out-of-doors man by nature—not one to let his pen do his imagining for him. He was no slave of the ink-bottle as some are, who cannot think without the feather of a goose in their hands, by way of a sometimes appropriate talisman. There is a well-known passage in one of the Roman Elegies to the effect that inspiration is to be sought more directly than within the four walls of a study, and that the rhythm of the hexameter is not best drummed with the fingers on a wooden table. And if it is true, as he tells, that "youth is drunkenness without wine," it seems to follow, according to his experience, that those two or three bottles of wine are not altogether needless as an aid to inspiration when youth is gone by.

The fellow-instance of imaginative work triumphantly carried on under the most admirable healthy conditions is that of Scott. He used to finish the principal part of his day's work before breakfast, and, even when busiest, seldom worked as late as noon. And the end of that apparently most admirably healthy working-life we also know. "Ivanhoe" and "The Bride of Lammermoor" were dictated under the terrible stimulus of physical pain which wrung groans from him between the words. The very two novels wherein the creative power of the arch-master of romance shows itself most strongly were composed in the midst of literal birth-throes. It was then he made that grimmest of all bad puns—"When his audible suffering filled every pause, 'Nay, Willie,'" addressing Laidlaw, who wrote for him and implored him to rest, "'only see that the doors are fast. I would fain keep all the cry as well as all the wool to ourselves; but as to giving over work that can only be done when I am in woolen.'" So far from affording any argument to the contrary, the history of the years during which his hand was losing its cunning seems to illustrate the penalty of trying to reconcile two irreconcilable things—the exercise of the imagination to its fullest extent, and the observance of conditions that are too healthy to nourish a fever. *À propos* of his review of Ritson's "Caledonian Annals," he himself says, "No one that has not labored as I have done on imaginary topics can judge of

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the comfort afforded by walking on all-fours and being grave and dull." There spoke the man who habitually and without artificial help drew upon his imagination at the hours when instinct has told others they should be employing not their fancy but their reason. The privilege of being healthily dull before breakfast must have been an intense relief to one who compelled himself to do unhealthy or abnormal work without the congenial help of abnormal conditions. Herder, in like manner, is accused by De Quincey, in direct terms, of having broken down prematurely *because* he "led a life of most exemplary temperance. . . . Surely if he had been a drunkard or an opium-eater, he might have contrived to weather the point of sixty years." This is putting things pretty strongly, but it is said of a man of great imaginative power by a man of great imaginative power, and may therefore be taken as the opinion of an expert all the more honest because he is prejudiced. A need must be strongly felt to be expressed with such daring contempt for popular axioms. At the same time "the German Coleridge" did not manage so very badly, seeing that he worked hard till sixty, and he allowed himself as much coffee as his exceptionally delicate nervous system would stand; so that in reality he seems to conform to the general rule by example rather than by way of exception. Scott is a far better type of the exception that approves the rule. Genius has been defined in as many different ways as there have been people who have tried to define it. But perhaps the most suggestive I have ever heard is the attempt to destroy an exceptionally strong constitution for the gratification of a mental tendency—the *physique* of an elephant, as I heard it roughly put, and the conduct of a slave-driver who is his own slave. There must be the exceptionally strong constitution to bear an abnormal strain and the effort by every means to do more than Nature when kindly treated will allow. The true working-life of Scott, who helped Nature by no artificial means, lasted for no more than twelve years from the publication of "Waverley" till the year in which his genius was put into harness; so that, of the two men, Scott and Balzac, who both began a literary life at nearly the same age, and were both remarkable for splendid constitutions, the man who lived abnormally beat the man who lived healthily by full eight years of good work, and kept his imagination in full vigor to the end.

That night and not morning is most appropriate to imaginative work is supported by a general consent among those who have followed instinct in this matter. Upon this question, which can scarcely be called vexed, Charles Lamb is the classical authority. "No true poem ever owed its birth to the sun's light. The mild internal light, that reveals the fine shapings of poetry, like fires on the domestic hearth, goes out in the sunshine. Milton's morning-hymn in paradise, we would hold a good wager, was penned at midnight, and Taylor's rich description of a sunrise smells decidedly of the taper." "This

view of evening and candle-light," to quote his commentator, De Quincey, once more, "as involved in the full delight of literature," may seem no more than a pleasant extravaganza, and no doubt it is in the nature of such gayeties to travel a little into exaggeration; but substantially it is certain that Lamb's sincere feelings pointed habitually in the direction here indicated. His literary studies, whether taking the color of tasks or diversions, courted the aid of evening, which by means of physical weariness produces a more luxurious state of repose than belongs to the labor-hours of day; they courted the aid of lamplight, which, as Lord Bacon remarked, gives a gorgeousness to human pomps and pleasures such as would be vainly sought from the homeliness of daylight." Those words "physical weariness," if they do not contain the whole philosophy of the matter, are very near it, and are at all events more to the point than the quotation from Lord Bacon. They almost exactly define that non-natural condition of the body which, on other grounds, appears to be proper to the non-natural exercise of the mind. It will be remembered that Balzac recommended the night for the artist's work, the day for the author's drudgery. Southey, who knew how to work and how to get the best and the most out of himself as well as anybody who ever put pen to paper, and who pursued the same daily routine throughout his whole literary life, performed his tasks in the following order: From breakfast till dinner, history, transcription for the press, and, in general, all the work that Scott calls "walking on all fours." From dinner till tea, reading, letter-writing, the newspapers, and frequently a *siesta*—he, also, was an heroic sleeper, and slept whenever he had the chance. After tea, poetry, or whatever else his fancy chose—whatever work called upon the creative power. It is true that he went to bed regularly at half-past ten, so that his actual consumption of midnight oil was not extravagant. But such of it as he did consume was taken as a stimulant for the purely imaginative part of his work, when the labor that required no stimulant was over and done. Blake was a painter by day and a poet by night; he often got out of bed at midnight and wrote for hours, following by instinct the deliberate practice of less impulsive workers. Now, bodily weariness is simply bodily indolence induced artificially; its production by hard walking, hard riding, hard living, or hard study, looks like an instinctive effort on the part of energetic men to put themselves for the time and for a purpose into the chronically unhealthy condition of naturally indolent men. Indolence, that is to say chronic fatigue, appears to be the natural habit of imaginative brains. It is a commonplace to note that men of fertile fancy, as a class, have been notorious for their horror of the work of formulating their ideas even by the toil of thought, much more by passing them through the crucible of the ink-bottle. In many cases they have needed the very active stimulant of hunger. The *cacoëthes scribendi* is a disease common, not to imaginative, but to imitative minds. Probably no hewer

of wood or drawer of water undergoes a tithe of the toil of those whose work is reputed play, but is, in fact, a battle, every moment, between the flesh and the spirit. Campbell, who at the age of sixty-one could drudge at an unimaginative work for fourteen hours a day like a galley-slave, "and yet," as he says in one of his letters, "be as cheerful as a child," speaks in a much less industrious tone of the work which alone was congenial to him: "The truth is, I am not writing poetry but projecting it, and that keeps me more idle and abstracted than you can conceive. I pass hours thinking about what I am to compose. The actual time employed in composition is but a fraction of the time lost in setting about it." "At Glasgow," we read of him even when a young man, "he seldom exercised his gift except when roused into action either by the prospect of gaining a prize or by some stirring incident." Campbell, if not a great man, was a typical worker. Johnson—who, whatever may be thought of his imaginative powers, was another type—struck off his *Ramblers* and *Idlers* at a heat when the summons of the press forbade his indolence to put off his work another moment; he did not give himself even a minute to read over his papers before they went to the printers. He would not have written "Rasselas" except for the necessity of paying for his mother's funeral; and yet he was a laborious worker where the imagination was not concerned. The elder Dumas had to forbid himself, by an effort of will, to leave his desk before a certain number of pages were written, in order to get any work done at all. Victor Hugo is said to have locked up his clothes while writing "Notre-Dame," so that he might not escape from it till the last word was written. In such cases the so-called "pleasures of imagination" look singularly like the pains of stone-breaking. The hardest part of the lot of genius, I suspect, has been not the emotional troubles popularly—and with absurd exaggeration—ascribed to it, but a disgust for labor during the activity of the fancy, and the necessity for labor when it is most disgusting. And, as it is not in human nature to endure suffering willingly, the mood in which such labor is possible calls for artificial conditions by which it can be rendered endurable.

The passing mention of Blake indirectly suggests an objection. Nature has thought fit to place an insuperable bar between painters and night-work: and yet the work of the painter is as imaginative in character as that of the poet, while painters have shown no tendency, as a class, to break down under the strain. Artists in form have not often followed the example of Michael Angelo, who stuck a candle in a lump of clay, and the lump of clay on his head, and chiseled till morning. But then writing is the exercise of the imagination, including conception as well as execution; painting is the record of previous imagination, and so belongs to the daylight, even according to Balzac's rule. Skill, intelligence, the eye and the hand, which work best under natural and healthy conditions, have to bear the

strain. Because his hand and mind work by day, it does not follow that the painter's fancy is not a night-bird—only, happily, it is not called upon to labor in its dreaming hours. Musicians, who might be expected to demand the conditions of imaginative literature in a tenfold degree, have, in fact, breathed as common air the stimulating and unhealthy atmosphere that authors only enter when they need it. Musical genius is, so to speak, a self-supporting fever, that finds in every sort of exciting stimulus not its artificial but its natural and healthy atmosphere. Exceptions, like John Sebastian Bach, prove the notoriety of the rule by the stress which is laid upon them. The manners and customs of great artists in sound tend to support the general rule concerning all imaginative work to an infinite extent, but it would be unfair to argue from those who breathe poison for their native air to those who merely use poison in order to escape from the common air of the unimaginative world.

It is notorious that creative genius is essentially of the masculine gender. Women are the imaginative sex, but the work, which Nature seems to have distinctly allotted to them, has been done by men. This really strange phenomenon is not due to the fact that women have written comparatively little, because, if it were, the little imaginative work they have done would have been great in quality, and would surpass in quantity the other work they have done. But it has not been great in quality compared with that of men, and, compared with the rest of their own work, has been infinitesimally small. No woman ever wrote a great drama; not one of the world's great poems came from a woman's hand. In their own domain of fiction women have been, and occasionally are, great realists, great portrait-painters, great masters of style, great psychologists—but not great inventors, and very seldom inventors at all. Probably everybody will be able to name off-hand one or two exceptions to what looks like a very dogmatic and sweeping piece of criticism—and probably everybody will name exactly the same one or two. Nobody dreams of looking for absolutely great imaginative work, in any branch of art, from a woman; and, when by chance it comes, the admiration it excites is multiplied by wonder. People say, "See what a woman can do"—not "See what women can do." In music, the typically imaginative art, wherein they have had a free and open career, it is legitimately dogmatic to deny them any place at all. Seeing, therefore, that the natural imagination of women is comparatively barren while the ordinary unimaginativeness of men is absolutely fertile, it is impossible to doubt that the way of work has something to do with the matter. And if examples tend to prove that creative genius among men instinctively works under artificial and unhealthy conditions of body, while work wherein the imagination is not tasked is for the most part carried on under the calmest and healthiest conditions, it would follow that women at large fail to produce great

creative work by reason of their good working qualities—because they do not in general use artificial stimulants and irregular modes of life to help their brains to wear out their bodies. They keep themselves broad awake in order to dream! They seek to do imaginative work, and take as models the lives of men who do unimaginative work—that is to say, precisely the opposite routine to that of men by whom imaginative work is done. These prove negatively what the examples of creative genius prove positively. If scholars toil late into the early hours, it is to continue their day's work, not to begin it. It is interest that chains them to the desk at midnight, not impulse that calls them there. All philosophers have not always been sober men; but they have taken their indulgences as refreshments and recreations—as interruptions to work, and not as its necessary accompaniments. If Balzac's may be taken as the type of the artist's life, Kant's may be taken as the type of the student's. The habits of both are equally well known. Kant also gave a daily dinner-party; but when his guests were gone he took a walk in the country instead of seeking broken slumbers in a state of hunger. He came home at twilight, and read from candle-light till bedtime at ten. He rose punctually at five, and, over one cup of tea and part of a pipe, laid out his plan of work for the day. At seven he lectured, and wrote till dinner-time at about one. The regularity of his life was automatic. It was that of Balzac save in fulfilling all the accepted conditions of health—early rising, early lying down, moderate daily work, nightly rest, regular exercise, and a diet regulated with the care not of a lunatic but of a physician. A cup of tea and half a pipe in the morning cannot be looked upon as stimulants to a man in such perfect health as Kant always enjoyed; and, if they can be, let it be observed that it was while engaged with these he thought about his work—it was his hour for what Campbell called his "*fuming* meditations." He certainly used no other stimulant to work, in the common sense of the word; but even he illustrates, in another point, the need of the mind for artificial conditions, however slight they may be, when engaged in dreaming. During the blind-man's holiday between his walk and candle-light he sat down to think in twilight fashion; and, while thus engaged, he always placed himself so that his eyes might fall on a certain old tower. This old tower became so necessary to his thoughts that, when some poplar-trees grew up and hid it from his window, he found himself unable to think at all, until, at his earnest request, the trees were cropped and the tower brought into sight again. Kant's old tower recalls Buffon's incapability of thinking to good purpose except in full dress and with his hair in such elaborate order that, by way of external stimulus to his brain, he had a hair-dresser to interrupt his work twice, or, when very busy, thrice a day. It is curious to note the touch of kindred between the imaginative *savant* Buffon and the learned artist Haydn, who could not work

except in court-dress, and who used to declare that, if, when he sat down to his instrument, he had forgotten to put on a certain ring, he could not summon a single idea. How he managed to summon ideas before Frederick II. had given him the said ring we are not informed. But even these trivial instances of caprice help to suggest that, when the fancy is called upon, the ordinary conditions of straightforward work must be considered at an end. Fancy dictates the terms on which she condescends to appear. Of Dickens we are told that "some quaint little bronze figures on his desk were as much needed for the easy flow of his writing as blue ink or quill pens."

But, unhappily, the terms dictated by creative fancy have not been and are not always so innocent as blue ink, coffee, late hours, or rotten apples. A true and exhaustive history of how great imaginative work has been done would be too sad a chronicle, and would be good for nothing but to recall biographical memories that are better forgotten. No doubt most readers will be able to supply from memory instances enough to judge for themselves how far the well-known examples here given exemplify and account for the connection of creative genius with a tendency to chronic suicide. And if the necessity of this connection be admitted, then the question arises, "How far is any man justified or not justified in adopting in intellectual matters the doctrine that the end justifies the means? If he feels—and biography speaks vainly if he is held to be mistaken in feeling—that the work for which Nature intended him must be left undone unless he deliberately elects to ruin his health, to become an awful warning to the white sheep of the social sheepfold and a stumbling-block to would-be imitators, which is he to choose?" All the branches of the question, all its most trifling illustrations, lead to that broad issue which has never yet been boldly faced or fairly answered. The strange manners and customs of men of genius have often enough been defended as unfortunate weaknesses by their apologists: it seems to me they ought either to be condemned as unworthy of men of sense and will, or else boldly asserted as the necessary instruments of the work that owes its birth to them—as the artificial means of producing strength out of weakness which a man who lives for his work *ought* to use. If creative genius is really an unhealthy condition, it must require unhealthy methods to produce and sustain its action. It is not the healthy oyster that breeds the pearl. Nor is this a dangerous theory. The oyster does not deliberately produce in itself the disease of pearl-bearing, nor can any man—it need hardly be added—give himself genius by adopting and abusing the artificial means that enable genius to work when it is already there. The disease suggests its appropriate conditions: the conditions clearly cannot bring about the disease. The morality of the whole question, and its application to any particular case, must be settled by everybody for himself; but a story of a hurdle-race at Gadshill, told in Mr. Forster's life of Dick-

ens, contains in a homely way the summing up of its philosophy. "Among other oddities we had a hurdle-race for strangers. One man—he came in second—ran a hundred and twenty yards and leaped over ten hurdles in twenty seconds, *with a pipe in his mouth and smoking it all the time.* 'If it hadn't been for the pipe,' I said to him at the winning-post, 'you would have been first.' 'I beg your pardon, sir,' he answered, 'but *if it hadn't been for my pipe* I should have been *nowhere.*' "—*Gentleman's Magazine.*

SKETCH OF DR. WILLIAM WHEWELL.

DR. WILLIAM WHEWELL stands highest in the literary world as the historian of science. His "History of the Inductive Sciences" is not a mere bald narration of the facts and details of scientific progress, but is a philosophical treatment of the subject, which shows the growth and advancement of principles or general truths. It is, in fact, an elaborate historical review of the processes of generalization, such as had never before been attempted. This work stands eminent among the scientific contributions of the past age, both on account of its historic erudition and its trustworthy representation of the broad inductions of modern scientific inquiry. It is a permanent work of reference in every scientific library; and the extent to which it has influenced the philosophical mind of the age is well illustrated by the acknowledgment of John Stuart Mill: that, if Whewell had not written the "History of the Inductive Sciences," the "Logic, Ratiocinative and Inductive," might never have appeared.

Dr. WHEWELL was born in Lancaster, May 24, 1794. His father was a joiner, and intended to have his son follow his trade. But while at school he showed such a remarkable talent for mathematics, together with evidences of more than ordinary ability in other branches, that it was decided to send him to Cambridge. He entered Trinity College, as Freshman, in 1813, at the age of nineteen. The following year he distinguished himself by winning the English Poetical Prize. He was graduated B. A. in 1816, with the honors of second wrangler in the Mathematical Tripos, was elected a Fellow, and soon afterward Tutor of Trinity College. He rapidly earned a reputation as a successful teacher, both in the class-room and as "coach," or private tutor.

He applied himself to mathematics and vigorously went to work to bring about a radical reform in the methods of teaching the physical sciences in England. In 1819 he published his first work, "An Elementary Treatise on Mechanics," designed for the use of students of the university. In 1820 he was elected a Fellow of the Royal Society, and we now find him contributing to the "Transactions" of

learned and scientific societies, and to scientific journals, papers on the tides, heat, electricity, and magnetism; and to the literary journals and reviews miscellaneous papers on subjects literary, historical, and metaphysical. In 1828 he was appointed Professor of Mineralogy in the university. In order to perfect his knowledge of that branch of natural science, he visited Germany and spent some time at the celebrated mining-schools of Freiburg and Vienna. He resigned his mineralogical professorship in 1833; published his treatises on "Statics," "Mechanics," and "Dynamics," and brought out his first great work, entitled "Astronomy and General Physics considered in their Relations to Natural Theology." In this work Dr. Whewell breaks connection with the traditions of the experimental school, and abandons Bacon and Locke, to range himself on the side of Kant, to whose philosophy he had become a convert while in Germany. He also endeavored, during this time, to make his countrymen acquainted with German literature and art, of which he was a warm admirer. He translated several gems of German literature, such as Goethe's "Hermann und Dorothea," and "The Professor's Wife," of Auerbach, and published "Notes on the Architecture of German Churches," which met with great success in England. Among other works of less importance published soon after, his "Thoughts on the Study of Mathematics as Part of a Liberal Education," and, particularly, his "Mechanical Euclid," gained considerable note. In 1837 he published his "History of the Inductive Sciences from the Earliest to the Present Times."

Dr. Whewell's thinking now seems to enter upon the road of philosophy. During this same year he published "Four Sermons on the Foundation of Morals," and in the following year (1838) he was appointed Professor of Moral Philosophy in the university. From this time forward he occupied himself almost wholly with moral questions. In 1840 he published a sequel to, or commentary on, his "History of the Inductive Sciences" under the title of "The Philosophy of the Inductive Sciences," which was afterward enlarged and published as three separate works under the titles of "History of Scientific Ideas," "Novum Organon Renovatum," and "On the Philosophy of Discovery." We may add to these a fourth, "Indications of the Creator," consisting of extracts bearing upon theology, from the "History" and "Philosophy of the Inductive Sciences." In 1841 he was appointed Master of Trinity, and was President of the British Association at its meeting in Plymouth. The same year he also put out another mathematical work, entitled the "Mechanics of Engineering." In 1845 he published his "Elements of Morality, including Polity," "Lectures on Systematic Morality," "On Liberal Education in General, and with Particular Reference to the Leading Studies of the University of Cambridge." The following year he issued another mathematical work on "Conic Sections; their Principal Properties proved Geometrically." In 1852 he published "Lectures on the History of Moral Philosophy in Eng-

land," and soon afterward, among others, a translation of Grotius's "Rights in Peace and War," a translation of Plato's "Dialogues," and, anonymously, a work entitled "The Plurality of Worlds," in which he argued that none of the planets, except the earth, are inhabited. This book had a great popularity, and excited much discussion. In 1855 he became Vice-Chancellor of the university, and retired from the professorship of Moral Philosophy, remaining, however, Master of Trinity. Among the last of his works was the editing, in 1861, of the mathematical works of Dr. Isaac Barrow, Master of Trinity in 1672. Dr. Whewell died May 5, 1866, from the effects of injuries received in a fall while riding on horseback. He was one of the most distinguished men that Trinity College has produced, and one of the best of its masters. He was a munificent benefactor to the college, to which he added one new court during his life, and at his death bequeathed his large fortune to the building of another, and to the founding of a professorship of International Law. Dr. Whewell was a large, strong, erect man, of the Johnsonian type, with a red face and a loud voice, an effective preacher, a vigorous controversialist, and a man of extensive and varied attainments, which were always at ready command. His memory was remarkable, but it was rather special, and took chiefly the direction of his studies. He could remember all about books and their contents with the greatest accuracy, but could not recollect the names of the Fellows of his own college. This was of course often wrongly interpreted; and very naturally so, it must be confessed, for Dr. Whewell's manner was marked by no little assumption of superiority. He was naturally aristocratic in feeling, and his pompous bearing among the college officials gave him the reputation of being arrogant. Still, he understood his own strength, and was not without excuse for a considerable degree of self-regard. A story is told of him which illustrates both his varied knowledge and his personal relations to his brother Fellows: He used frequently to so overwhelm the company at the Fellows' table with his learning, that a conspiracy was at length formed to put him down. A number of them, on one occasion, crammed up on Chinese music, from scattered articles in old reviews, which they supposed he would not be acquainted with, and then made the state of music among the Chinese the subject of a seemingly casual conversation at dinner. They were highly gratified with the apparent result; for, contrary to his usual custom, Dr. Whewell remained silent. When, however, they had nearly talked themselves out, he remarked: "I was imperfectly and to some extent incorrectly informed regarding Chinese music when I wrote the articles from which you have drawn your information." The conspiracy was a failure; the Fellows were disgusted, and the dignified doctor remained acknowledged master of the situation.

CORRESPONDENCE.

TO WHAT EXTENT IS EVOLUTION VISIBLE?

To the Editor of the Popular Science Monthly:

"It is less unphilosophical to suppose that each species has been evolved from a predecessor by a modification of its parts, than that it has suddenly started into existence out of nothing. Nor is there much weight in the remark that no man has ever witnessed such a transformation taking place."—(Draper, "History of the Conflict between Religion and Science," p. 192. "International Scientific Series," No. 12.)

There stands, in a window of my wife's sitting-room, a potted slip of geranium. To-day, I heard her remark, "I can see that this grows now, every day." In what sense is this true? By remembering its size and condition of yesterday, and comparing it with its present dimensions and conditions, an increase and change are demonstrable. It certainly has grown. But, if we were to sit down at sunrise and watch unceasingly until sunset, or by lamplight continue the vigil until sunrise again, we would in all this time have seen no enlargement of the main stem—no unfolding of a leaf-bud; still, both these changes have taken place within twenty-four hours, and, of course, in full view.

Is it not true in the same way, but far less rapidly, that the changes in animal life are constantly occurring—so gradually, that we cannot mark and measure the progress, but, like the plant, can appreciate the changes when considerably advanced? The birds, the fishes, the insects of to-day are the same that our grandparents knew. Linnæus would recognize our white-headed eagle, if he could see one now; yet, in truth, they are not wholly the same. Just as we will realize, in the coming May, a great change in the forest-trees, then clothed in verdure, and now bare and seemingly lifeless, will not, in the life-giving spring of a coming æon, the changes not now discernible be seen, admired, and studied, by the people of that time? Taking up some of the more familiar objects about me, I have endeavored to see if there was not a possibility of detecting some trace of changes now in progress, reminding one of the changes of a growing plant.

The change now in progress in any species, say of fishes, is to become, if I am correct in my surmise, visible in fifty centuries or more. From what we can now learn of the fish, can we determine the direction of the change; can we predict its character? Our slip of geranium has to-day a small outgrowth at one side of the stem; elsewhere the bark is smooth and unbroken. If, by the microscope's aid, we study the character of the structure of the main stem, if we learn every detail of the physiology of the plant, we conclude that it is a living, healthy organism, not depending upon the leaf-bud. As a mere bud, it is not a necessity; but, as a full-blown leaf, it is. If, now, we carefully study the habits of any of our common fishes, we will find in them certain peculiar habits, which may be compared to the leaf-bud; and I believe these habits, in many cases, are only faint traces of a coming change that will expand like the opening leaf-bud, into a fully-established characteristic in the far-distant to-morrow of a coming age.

In this way—to this extent—is not evolution visible?

As an example, let me call your attention to our well-known mud-minnow (*Melanura limi*). This fish I have very carefully studied for several years, and seldom fail to see something peculiar in its habits, every additional hour I spend in watching them, whether in an aquarium or their native haunts. On observing the movements of some remarkably large specimens lately, in an aquarium, I was forcibly struck with the peculiar use they made of their pectoral fins. These fins, in most fishes, are kept parallel, or nearly so, with the body, and are usually thin, transparent, and with very flexible rays. These conditions, which vary

in the thousands of species of fishes, do not obtain in the case of the mud-minnow The membrane is dense, the rays numerous and strong, and the fin is held at a right angle with the body when the fish is in an horizontal position, and nearly so whatever other position may be assumed. The ventral fins, likewise stiff and strongly rayed, when the fish is swimming, are not much used, but as soon as the animal comes to a rest they are spread out, and, with the pectoral fins, now stiff and motionless, they form four legs that support the body, just as a salamander does. Indeed, the likeness goes further, and the body is curved frequently when at rest, and remains so; the head turned to the right or left, the tail in the opposite direction. No one can fail to see the salamandrine appearance of this fish in this position. Now, if we follow up the habits of the fish, what unfish-like—if I may use the expression—habit other than this can we detect? Knowing its predilection for thick and muddy waters, I find it not only conceals itself in the mud during the summer, but it deeply embeds itself and regularly hibernates; and in times of drought will live, as I have determined by experiment, twenty-eight days, in stiff mud, far less moist than the usual ditch-bottom, during a dry summer. This must be recollected in connection with its salamandrine aspects when in water. Again, by experiment, I find that this minnow, out of water, will outlive all other fishes of our streams, except the eel and possibly the catfish. My experiments showed it outlived a common sunfish just 500 per cent.; a roach, 1,500 per cent.; and a catfish and mud-minnow, taken from the water together, and kept thirty-five minutes in the air, were both very sick when replaced in the aquarium. The catfish revived in three minutes; the minnow in eleven. This unusual ability of retaining life out of its natural conditions and surroundings is just such a peculiarity as one might look for, in this species, having once noticed the peculiarity of the fins I have mentioned. To-day, however, I noticed for the first time a movement on the part of the mud-minnows, in my aquarium, never before detected, and which made the fins more leg-like than ever. Two specimens were resting, as we have described, on the tips of the pectoral and ventral fins. Coming near them suddenly, one, and then the other, moved several "steps," i. e., they gave their fins a leg-like motion, which left

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faint impressions, thus ((((upon the sand. I had never seen such fin-movements on the part of this fish before, nor have I since, although for a week past I have carefully watched them.

Taking, now, into consideration the habit of resting on the tips of the fins; of giving the body a serpentine position, often maintained for many minutes; of burrowing in the mud; and able to withstand the atmosphere for a remarkable length of time; to which I think I may add walking on its fins—may we not see in all these a "leaf-bud," as it were, which in the far future will expand into an air-breathing, salamandrine animal?

Have we here really caught a faint glimpse of evolution?

Since the above was written, I have received and read Schmidt's "Descent and Darwinism." On page 130 he quotes from Lyell, as follows: "In a word, the movement of the inorganic world is obvious and palpable, and might be likened to the minute-hand of a clock, the progress of which can be seen and heard; *whereas the fluctuations of the living creation are nearly invisible, and resemble the motion of the hour-hand of a timepiece. It is only by watching it attentively for some time, and comparing its relative position after an interval, that we can prove the reality of its motion.*" This quotation is the same idea far more lucidly expressed; and, had I been aware of its existence, my remarks would have remained unwritten. As it is, are they not a confirmation of my belief that evolution is, after a manner, visible, and do we not find an instance of this in the mud-minnow?

CHARLES C. ABBOTT, M. D.

PROSPECT HILL, TRENTON, N. J., *March* 16, 1875.

EDITOR'S TABLE.

TO OUR PATRONS.

SIX volumes of THE POPULAR SCIENCE MONTHLY are now published, and with this number it enters upon its fourth year. We remind our friends of this, that they may renew their subscriptions, and we trust they will urge their neighbors to join them in taking the MONTHLY, as thereby it may be obtained at a cheaper rate. The public press has been saying these three years that this is the most valuable and instructive magazine in the country. Yet our subscription list by no means comports with such a standard of excellence; for the best thing ought certainly to be the best sustained. Although our circulation is fair, it is still far behind that of those periodicals which leave science out or consign it to the department of scraps. Let no one suppose that in helping this MONTHLY to new readers they are ministering to a speculation; the time is a long way off when a first-class scientific magazine will enrich anybody. We have before us the more urgent question of making the MONTHLY pay moderate prices for the work that is done on it, and earn the means of its own improvement—objects which can be secured exactly in proportion as it is sustained by the public.

It should be remembered that THE POPULAR SCIENCE MONTHLY stands alone in doing a special and important work. It was not started merely to add another to the list of magazines, the chief of which are so nearly alike that they are mutually replaceable; but it was started to furnish a very *different* magazine from any the people could get. In so far as our age is an age of ideas, the first great fact about it undoubtedly is, the ascendency of science as a power that is moulding the mind of the period. The extension of scientific knowledge is affecting all the interests of society. Agriculture, the manufacturing arts, locomotion, the physical conditions of health, the economy of the vital and mental powers, are all influenced by it to a degree never before experienced. These are confessedly within the circle of interests embraced by science, but that circle is steadily enlarging. Higher questions are being constantly brought under scientific treatment. To this great movement of thought characteristic of the time, our periodicals gave no adequate expression; and it therefore became necessary to begin a magazine that would put its readers in honest possession of the broadest conclusions of scientific study, as well as the immediate results of experimental research. Without being an organ of propagandism, or representing any clique or school of doctrine, we shall continue, as we have done, to give the fresh facts and the advanced conclusions of science, and we ask the earnest coöperation of all who sympathize with this work.

LACTOMETRY AND MORALS.

THERE is an old disagreement between society and the milkman. The latter is alleged to be depraved, and, as a consequence, to adulterate his milk with water. Ethical considerations do not seem to influence him. Though commanded to sell unto others only such milk as he would have others sell unto him, he prefers what he considers as a still more golden rule.

Now, we are inclined to regard the milkman with becoming charity. We cannot believe that he is a sinner above all other men. What he needs more than any thing else is, to be delivered from

temptation. His evil opportunities are too many for him. Nor is it of much use to preach to him from the door-steps concerning the wickedness of his ways; because he will ask you to read from the newspaper you have in your hand the last reports about the rings, frauds, corruptions, stealing and plunder on a grand scale, in high places, and on the part of representative men whom the people delight to honor. Peculation, misappropriation, overreaching, and sharp practice, he tells you, are the order of the day—the rule, the fashion, and that a man "might as well be out of the world as out of the fashion." He tells you that business rivalries are desperate, that men must live, and that the world must be taken as it is. The milkman is of opinion that, if the business standards of the community could be raised to a level with his own practice, a long stride would be taken toward the millennium. He refers you to a report to the Board of Health in this city, in which it is stated that chalk, flour, starch, emulsion of almonds, sugar, gum, dextrine, borax, turmeric, annotto, soda, and sheep's brains, have been used for doctoring milk; but that, in hundreds of examinations of milk furnished to the citizens of this metropolis, none of these ingredients have been detected. Water, to be sure, is alleged to have been used, but what is more wholesome? and what are the secluded spring and the ready pump for, if not to supply it? He reminds you that societies are organized all over the world to get people to drink more of it; that milk is mainly aqueous, to begin with; that there is no natural standard of the proportions of this constituent: that the business of dispensing it is a detestable drudgery; that the milkman must be astir and abroad while other people slumber; that he has to rout the lazy servant-girls with unearthly screeches, and then wait till they are pleased to make their appearance; that there is waste with every pint delivered; that bills are hard to collect; that though his conscience be as white as the contents of his can, yet is he ever charged with cheating; that his rascally competitor is underselling him and he perfectly understands the cause; and, finally, that the losses and drawbacks of business have to be covered in different ways, while, if a little innocuous water is added to the milk, nobody is worse for it, and nobody can find it out.

Now, it is useless to reason with the milkman, or to exhort him to raise his conduct to the standard of pure and absolute rectitude, for, even if he should repent, he would be pretty sure to backslide. Yet the case against him is not to be given up; where homilies fail, science comes to the rescue; and, if its indications are followed, the milkman and his customer may be brought into tolerably harmonious relations.

How far the craft have wandered away from the paths of rectitude in this region, and how their venial transgressions swell into an immense daily burden upon the community, are well illustrated by the following statement from Prof. Chandler's report to the Metropolitan Board of Health in 1870. He says:

"The average percentage of pure milk, in the adulterated article with which the city is supplied, is 73.28; or, in other words, for every three quarts of pure milk, there is added one quart of water. It was stated at the convention of milk-producers and dealers, held at Croton Falls, in March, 1870, that the total amount of milk supplied to the cities of New York and Brooklyn, from the surrounding country, was about 120,000,000 quarts per annum. To reduce this to the quality of our city supply, requires an addition of 40,000,000 quarts of water, which at 10 cents per quart, costs us the snug sum of $4,000,000 annually, or about $12,000 per day."

Now, granting that there is a great deal of money spent in New York, in worse ways than in buying water at ten cents a quart retail, it is still desirable to introduce more equity into these lactic transactions. The milk-consumer is

entitled to have what he pays for, and he can find out very satisfactorily what it is that he pays for, by the employment of the lactometer.

Good milk consists of about 88 per cent. water, combined with about 12 per cent. of solid matter dissolved or diffused in it, which makes it heavier than water. This increased relative weight is known as its specific gravity, and water being taken as 1000, the specific gravity of milk varies from 1023 to 1034. Without inquiring into the proportions of its several solid constituents, the lactometer determines their amount by indicating the specific gravity of the sample tested. The instrument is simply a glass tube closed at the lower end, and properly weighted, with a scale affixed, which shows the result when it is floated in a sample of milk. Milks from different cows and at different times vary in richness and poorness, so that it becomes important to fix such a standard that all samples which fall below it shall be classed as adulterated, or condemned as unmarketable. The New York Board of Health has been engaged for a considerable time, under the intelligent direction of Prof. Chandler, in investigating this subject, and, as a result of very extensive observations, they have fixed upon a specific gravity of 1029 as a fair minimum standard for pure milk, so that, "whenever the gravity falls below this number, the milk may be considered as containing an excess of water and consequently as poor in quality, or adulterated."

The standard adopted is, beyond doubt, sufficiently low. A German chemist tested the milk of 124 cows, and found the maximum specific gravity to be 1034.3, the minimum specific gravity to be 1029.5, and the mean 1031.7. Hence the standard of merchantable milk adopted by the New York Board of Health is lower than the poorest milk from these 124 cows. It may be remarked that milk of 1034 will bear an addition of 16.67 per cent. of water to reduce it to 1029.

This standard has been made legal in New York—that is, a dealer selling milk below 1029 is liable to a fine. Whatever may be the result of this policy, a most important step has been taken in fixing a minimum standard, and thus making it possible for milk-buyers, quickly and certainly, by the use of the instrument, to ascertain whether the character of the article they are purchasing is above or below it. We say, then, to every householder interested, get a lactometer. Taglibue, of 69 Fulton Street, New York, makes and sells them for $1.25 apiece, with the scale adopted by the New York Board of Health. The instrument is perfectly simple, and will last a hundred years, with care, but it is not a good thing for children to play with. On a card accompanying it, we read: "Fill the jar with the milk to be tested; allow it to cool to the temperature of 60° Fahr., then immerse the lactometer and notice the mark on the scale that is level with the surface of the milk, which will show the quality." The standard of pure milk adopted is marked P, and is taken as 100 on the scale. If the lactometer stands at that point, the milk is legal. If it sinks below it the milk is too thin, and the point in the scale at which it stands indicates its excess of water. If the mark P stands above the surface, the milk is richer than the standard, and the scale shows its superior quality. Of course, the instrument cannot give an analysis of the milk, and if a milkman reduces a high grade of milk to a somewhat lower standard, by admixture of water, the lactometer cannot show it; but it will tell exactly the quality of the milk every time, so that the buyer may know how he is being served. The general use of the lactometer could not fail to exert a beneficial influence upon the morals of the milk-trade.

DEAN STANLEY'S SERMON.

In another part of the MONTHLY will be found a report, derived from the London *Times*, of a late discourse of the Dean of Westminster, which has made a profound sensation in England. It was delivered in Westminster Abbey, on a very impressive occasion, the funeral of a philosopher who had done more than any of his contemporaries to vindicate the sharply-contested doctrine of the government of the world by unvarying law rather than by providential interventions; and who, through evil report and much denunciation, had successfully asserted the vast antiquity of the earth and of the human race. To add to the solemnity of the occasion, if it were possible, the queen, the "Defender of the Faith," and the head of the English Church, caused to be laid on the coffin a memorial-wreath, as a mark of her esteem.

The guiding principle of Lyell's geological opinions was, that there never has been any variation in the laws and operations of Nature. This principle had long previously been established as the corner-stone of scientific astronomy, both in the prediction of future celestial events and in the verification of old observations. If an eclipse of the sun or moon be recorded by Greek, or Chaldean, or Chinese historians, the astronomer, without hesitation, resorts to retrospective calculations, and determines its exact date. Epochs in chronology have been settled in that way. Or, looking forward with prophetic eye, he declares that, at a specified moment, there shall be such and such a conjunction of the satellites of Jupiter, or, a century hence, a transit of Venus. Implicitly relying on forecasts of the kind, the position of the moon among the stars, and other phenomena of the celestial bodies, the mariner trustfully finds the place of his ship at sea, and determines his proper track. Nautical almanacs teach us what prophecy really ought to be.

Lyell transferred the principle from the heavens to the earth. He discovered that the modeling of her surface had been accomplished by forces that are now, and ever have been, in operation; that the summer sun and wintry frosts, that rains, and winds, and rivers, and glaciers, and the ocean, worked always as they work now. But this implied the lapse of enormous periods of time. The six days of the orthodox creation, and the 6,000 years of orthodox chronology, were absolutely inadequate.

Unwilling needlessly to give offense to those who were not emancipated from the legends of their childhood, who still linger among popular theological conceptions, and find difficulty in enlarging their field of view, he never offensively, but always modestly, put forth the consequences of his new facts, very often suggesting rather than proclaiming them. When the first discovery of the vast antiquity of the human race was made—a discovery in which he took a leading part—he scrupulously observed the same course, and in this set an example to those obstreperous theologians whose insolent denunciations of science are founded often on ignorance, and not infrequently on less excusable grounds. "We now know," says Dean Stanley, "perfectly well, from our increased insight into the nature and origin of the early biblical records, that they were not, and could not be, literal descriptions of the beginning of the world. It is now clear to all the students of the Bible that the first and second chapters of Genesis contain two narrations of the Creation side by side, differing from each other in almost every particular of time, and place, and order. It is now known that the vast epochs demanded by scientific observation are incompatible with the 6,000 years of the Mosaic chronology and the six days of the Mosaic creation."

We ask attention, in the interests of truth, to the grave import of these

words from one of the most learned and religiously earnest divines of our time. What do they imply? Two things inevitably: first, the abandonment to Science of those cosmological problems over which Theology has hitherto claimed a divine right; and, second, the surrender to critical investigation of the nature and source of those narratives which have been hitherto so implicitly trusted. Dean Stanley is far from being alone in his views; they are shared by many other eminent clergymen who recognize that the Mosaic account of the Creation is without authority; and yet no part of Dr. Draper's celebrated book on the "Conflict between Religion and Science" has been so bitterly denounced by theologians as his remarks on the authenticity of the Pentateuch. He ventured a bold prophecy that the originals of the legends of the creation, the garden of Eden, the development of Eve from one of the ribs of Adam, the fall of man, the Tower of Babel, and the confusion of tongues, would be discovered in the clay libraries of the revived Mesopotamian palaces, as that of the Deluge had been; and, already, though only a few weeks have elapsed, it appears that they have been so found. How are they to be interpreted? When the legend of the Deluge was discovered by Mr. Smith, the agent of the London *Telegraph* newspaper, in these cuneiform tablets, it was hailed with triumph by biblical scholars, who looked upon it as a wonderful and unexpected testimony vouchsafed to these later days in behalf of the story of Genesis and the authenticity of the Pentateuch. It was supposed that the universal deluge had now been proved to have taken place. But another and very different view of the case has emerged, which is, that these legends, instead of being corroborative testimonials of the Pentateuch narration, are rather the originals from which it was derived. Into the question thus opened, although of great interest, we do not enter, but may say that, if this view proves the correct one, Assyrian explorers will hereafter be at a discount. Their discoveries will be classed with those of astronomers, geologists, and anthropologists. The theologians will find in them matter for merriment; and the digger into the mounds of the Tigris must get ready to be denounced as an atheist.

And yet Dean Stanley's sermon inspires us with hope that a better day is dawning. In the highest ecclesiastical ranks—and remembering the flowers that were laid on the coffin—in the highest political ranks, there is arising a spirit of liberality which more than sympathizes with the life of those great and good men, who, like Sir Charles Lyell, do not hesitate to encounter the prejudices and ignorance of their contemporaries for the sake of the truth, who invest its pursuit with the sanctity of a religious duty, and consider practical piety to consist, not in the noisy clamor for dogmas about which the human race will never agree, but in a submissive study of the revelation of Nature, and a courageous declaration of what they find in its records.

LITERARY NOTICES.

NATURE AND LIFE. Facts and Doctrines relating to the Constitution of Matter, the New Dynamics, and the Philosophy of Nature. By FERNAND PAPILLON. Translated from the second French edition, by A. R. MACDONOUGH, Esq. New York: D. Appleton & Co. 363 pages. Price, $2.00.

THE readers of THE POPULAR SCIENCE MONTHLY cannot fail to learn with pleasure that the complete essays of this gifted young author are now accessible in a single compact volume to the American public. Several of Papillon's masterly articles have appeared in our pages, and they awakened so deep an interest in the subjects considered, and were read with so much admiration, that it was felt to be important that all his principal papers should be reproduced in a separate issue. Of the charac-

ter of these compositions it is hardly necessary to speak. They are not only written with great clearness, force, and eloquence, but they evince a subtile perception and a strong grasp of the higher problems of modern scientific thought. Beyond doubt the French lead the world in the arts of lucid and attractive scientific exposition; and Papillon stands eminent among his countrymen in the display of this excellence. Although dealing with the most complex questions, and surveying the great phenomena of life on all sides, and especially in its dynamical aspects, yet there are a glow and a fascination in his pages which we do not hesitate to say are unsurpassed in modern scientific literature. Nor has the work lost aught of these impressive characteristics in its English dress. Papillon has passed prematurely away, but Mr. Macdonough has done justice to his memory by this brilliant reproduction of the Frenchman's work, by which a distant and foreign people will be able to appreciate his genius.

Papillon's view as a thinker, and the spirit of his scientific studies, are so admirably presented in his brief preface, that we quote it in full:

"This volume contains a series of essays written and published at different times, some of a general character, and others more special, and all relating to the activity of natural forces, especially those of life. The mere bringing together of these fragments has presented an opportunity of completing a methodical and uniform whole, combining exactness in details with generality of doctrines, and distinctly tracing the precise aspect of each group of phenomena in the picture of the close and universal relations that bind the whole together. An exposition is thus offered under an elementary form, in language freed from technical dress, of the most essential truths established of late by physics, chemistry, and biology, regarding the mechanism of natural forces, and the arrangement and combination of the fundamental springs of being in the world, especially in the living world. I indulge the hope that such a work might meet a kindly welcome from minds, ever increasingly numerous, that regard science as the subject neither of idle curiosity nor of passing entertainment, but as the object of earnest sympathy and of serious examination. Such, at least, is the principal purpose of this book.

"It has another, also. The evident disposition of the present day is to repose infinite hopes on the natural sciences, and to expect unlimited benefits from them. I certainly shall not view this inclination as an illusion, and this volume sufficiently attests the high value I set upon all that can encourage and foster such feelings. But precisely because I am not suspected of enmity to those sciences, it has seemed to me the more necessary to indicate a fatal mistake accompanying those commendable sentiments; I mean the mistake of those who, after loudly praising the excellence of science, denounce the weakness and deny the authority of metaphysics.

"Now, my reader will come upon more than one page manifestly inspired by the conviction that science, properly so called, does not satiate the mind eager to know and to understand, and that therefore metaphysics holds a large and an authorized place in the activity of human thought. While I have retouched every thing in these essays which seemed to me, from an exclusively scientific point of view, susceptible of a higher degree of exactness and precision, I have, on the contrary, preserved with jealous care the literal tenor of all the pages expressly written under the influence of that conviction. And I have done so, not because of any peculiar value in those reflections, many of which are nothing more than a very imperfect representation of my way of seeing, but because those reflections were then made for the first time, with absolute spontaneousness, and without the slightest system or premeditation. The reader will thus be able to see how general ideas naturally emerge from deep and close contemplation of a group of various details, how forcible their unsought impression is; in other words, how surely thought, following orderly and regular evolution, without studied intention as without dogmatic aim, arrives at the loftiest philosophic certainties.

"The thinker who freely seeks for truth, continuously changes his position in his aspirations toward mind and the ideal. He deserts the regions of phenomena and concrete things, to rise to those of the absolute and eternal. The farther he withdraws from the former, which had at first absorbed all his attention, the more strikingly does the perspective in which he viewed them alter. At last, he discerns nothing else in them but spectres without substance, and delusive phantoms. And in the degree and extent of his drawing near to the eternal and the absolute, reality comes more surely

within his ken, and he gains a more vivid feeling and a keener conception of it. He measures the distance he has traversed, and values the worth of his own contemplations by the fullness of lucid clearness which enlightens his faint view of the first principles of things, and by the depth of humble reverence with which he bows before the mysterious Power which created all!

"CONCARNEAU (FINISTERRE), *May*, 1873."

THE MICROSCOPE AND ITS REVELATIONS. By WILLIAM B. CARPENTER, M. D., F. R. S. Fifth edition. 848 pp. Price $5.50. Philadelphia: Lindsay & Blakiston, 1875.

THIS standard work on the microscope has been carefully revised by the author, so as to present the latest improvements in modern instruments. It also includes the new methods and principles of Dr. Royston-Piggott, which have lately been the subject of so much discussion among microscopists; it likewise gives the latest results of microscopical study. It is a volume of goodly size, containing 449 woodcut-illustrations, and 25 plates illustrative of its wide range of subjects, and forming a standard and complete guide to the use of the microscope. The author's object throughout is to direct the possessor of a microscope in the *intelligent* study of any department of natural history for which he may have a taste, or his circumstances afford him the facilities of pursuit; and, again, to meet the wants of those who, coming to the study of minute animal and vegetable life with no scientific preparation, yet want something more than a mere sight of them. Of his use of scientific terms the author says:

"Some . . . may think that he might have rendered his descriptions simpler by employing fewer scientific terms. But he would reply that he has had much opportunity of observing among the votaries of the microscope a desire for just such information as he has attempted to convey; and that the use of scientific terms cannot be easily dispensed with, since there are no others in which the facts can be readily expressed. As he has made a point of explaining these in the places where they are first introduced, he cannot think that any of his readers need find much difficulty in apprehending their meaning."

Dr. Carpenter recognizes the impossibility of keeping pace with the rapid extension of knowledge over every part of the constantly-widening field of microscopic research, to say nothing of furnishing an exhaustive treatise on each of its many departments, in the limited compass of his book, the original purpose of which is to impart *general* guidance, rather than *special* instruction; and, instead of attempting the impossibility of teaching his reader all there is to be learned, he is put in the way of learning it from that best of all teachers, *experience*. And so, in the applications of the microscope, the proportion of space allotted to the different departments has been determined more from their special interest to the amateur microscopist than their physiological importance, and more space and treatment in detail are given to subjects having no special sources of information than to such as are the subjects of special treatises.

The first five chapters, embracing 269 pages of the work, treat respectively of the principles of the microscope, its construction, accessory apparatus, management of the microscope, preparation of objects, etc., while the rest of the work is devoted to the practical applications of the microscope in the study of minute forms of animal and vegetable life, and its uses in geology, mineralogy, and chemistry.

HEALTH; A Hand-book for Households and Schools. By EDWARD SMITH, M. D., F. R. S., Author of "Foods," etc. 198 pages. Price $1.00. New York: D. Appleton & Co.

UNDER the general title of "The Popular Science Library," it is proposed to issue a series of neat and attractive volumes at the moderate and uniform price of a dollar each, that shall treat of the most important and interesting scientific subjects in a way suited for general readers. The books will be original, translations, reprints, and abridgments, with illustrations when necessary, and will take a free range in the selection of subjects, giving prominence to those that are practical, but aiming to represent all the aspects of science which are of general or of prominent interest. Dr. Smith's volume on "Health" was issued first, and is a plain, practical, useful book, which aims only to give valuable information for everybody, in a form which anybody can under-

stand. Dr. Smith never paid much attention to the elegances of literature, and cared only to make his statements clear, intelligible, and adapted to the wants of his readers, and, while the pages of this little volume will be found to contain no fine writing, they are filled with compressed and simplified statements of extreme importance in relation to Food, Diet, Clothing, Exercise, Rest and Sleep, Cleanliness and Bathing, Ventilation, Mental Work, the Hygiene of the Senses, Personal Habits and Conduct, Sick-room Management, etc., etc. The volume is freely illustrated, and we know of no hand-book of health that contains within its compass more of the knowledge that should be universally diffused than this. It would be an excellent primary text-book of health for adoption in schools.

THE NATURAL HISTORY OF MAN. By A. DE QUATREFAGES. Translated from the French by ELIZA A. YOUMANS. 12mo. Pp. 152. With Numerous Illustrations. New York: D. Appleton & Co.

POPULAR SCIENCE LIBRARY, NO. II.

THIS volume contains the substance of a course of lectures delivered to workingmen by A. De Quatrefages, a distinguished Professor of Natural History at the Museum, in Paris, and one of the eminent founders of anthropological science. These lectures have been extensively circulated on the Continent, in different languages; and the translations of several of them, printed in this magazine, were received with such favor as to induce their republication in a connected form. Prof. De Quatrefages is an acute and discriminating observer, and an ardent cultivator of science, but with strong conservative tendencies of thought. At the outset he announces that he shall treat the subject not as a philosopher or a theologian, but in the pure light of natural science.

Contrary to Agassiz, he takes the ground that all men form but a single species, though of different races. He holds that the origin of man must be referred to a date much more remote than has usually been allowed, and that his original locality was confined to a narrow spot in Central Asia. As to the origin of man, Prof. De Quatrefages believes that science is unable to furnish any clew to the mystery, although he insists that, if science cannot say whence man came, it can say positively whence he did not come, and as a teacher of science he opposes the idea that man is a transformed and perfected animal. That the book may fairly represent the present state of opinion upon this subject the arguments on the other side of this question are briefly given in an appendix. As an elementary work upon this subject, these lectures will be found remarkable for clearness and simplicity of statement, felicity of illustration, vivacity of style, and skill in bringing large questions within the range of ordinary apprehension. It is the most admirable popular introduction to the races of mankind that has yet appeared.

HEREDITY: A Psychological Study of its Phenomena, Laws, Causes, and Consequences. From the French of TH. RIBOT, author of "Contemporary English Psychology." New York: D. Appleton & Co. Pp. 393. Price, $2.00.

WE cannot be too often reminded that it is the essential character of science to winnow, limit, verify, and extend the ordinary knowledge of mankind. The germs of science are given in common experience, and undergo gradual development, until they take the shape of proved and formulated principles. The subject of the volume before us forms an excellent illustration of this tendency. Heredity, or the transmission of qualities from parents to offspring, has been vaguely recognized as a verity of Nature for thousands of years; but it was at the same time considered so obscure and capricious a thing, that it could never be reduced to law, or become the proper subject-matter of science. But all that is now past. The principles of physiological heredity have been elucidated, and are now so clear and well established that they are brought to the test of every-day practice; and the law is so sure, that the skillful breeder is able to mould his stock in any direction, and to realize almost any ideal of desirable physiological characters.

In the world of mind, also, there has long been an uncertain recognition of the fact of heredity, and the descent of special mental traits in families is within nearly everybody's observation. But it was currently believed that such observations were

rare exceptions, and that nothing like a general law of the descent of mental traits could be established in the field of mind. But this error must now be regarded as abandoned. With the establishment of heredity as a biological law, or in the field of life, the presumption immediately became strong that it must also hold in the field of psychological phenomena. From the metaphysical point of view in which mind is regarded as an abstraction detached from organization, the law of heredity would probably never have been arrived at; but modern scientific psychology, which regards psychical phenomena as rooted and based in vital phenomena, passes naturally to the question as one of the necessary correlations of the higher organic science. And so it has come about that this principle of inherited mental predispositions and character, from being universally discredited as a baseless doctrine, is now admitted as a great truth, and not only so, but as a truth which forms the corner-stone of the latest philosophy. Among the students of mind, there is an old and inveterate quarrel about the origin of our ideas—one school holding that they are intuitions existing in an abstract mental world, and independent of all experience; and another school holding that all ideas are derivable from the experience of individuals. Herbert Spencer has shown that there is a partial truth in both these views, and that they are capable of essential reconciliation through the principle of the evolution of faculties by inherited experience.

So prominent has this doctrine become in recent inquiry, and so profound is its importance, that there has been an imperative need of some work that should deal distinctly and broadly with the subject, and present its scientific aspects in a form suitable for popular study. Such a work we now have from Prof. Ribot. Mr. Galton's work on "Hereditary Genius" is a valuable contribution to the subject, but it is very far from being complete in its exposition, and its main facts are presented in a form somewhat difficult for the reader to deal with. Prof. Ribot's work is systematic and full, taking up the subject under the four successive departments of the facts, the laws, the causes, and the consequences of heredity.

The following passage, from the conclusion of the work, will give an idea of the author's style, and of the method of his argument. In summing up all *facts* in favor of psychological heredity, he says:

"As regards specific characteristics" (i. e., those which distinguish one species from another), "heredity comes before us with the evidence of an axiom. In the physical, as in the moral order, every animal necessarily inherits the characteristics of its species. An animal which should possess, with the organism of its own species, the instincts of another, would be a monster in the psychological order. The spider can neither have the sensations nor perform the actions of the bee, nor the beaver those of the wolf. Just so in one and the same species, whether animal or human, the races preserve their psychical precisely as they do their physiological characteristics. . . . Under the specific form, then, mental heredity is unquestionable, and the only doubt possible would have reference to individual characteristics. We have shown, from an enormous mass of facts, that the cases of individual heredity are too numerous to be the result of mere chance, as some have held them to be. We have shown that *all forms of mental activity* are transmissible—instincts, perceptive faculties, imagination, aptitude for the fine arts, reason, aptitude for science and abstract studies, sentiments, passions, force of character. Nor are the morbid forms less transmissible than the normal, as we have seen in the case of insanity, hallucination, and idiocy."

The book consists of four parts, as we have remarked, under the headings indicated in the sub-title. In Part I. we have chapters on the Heredity of Instincts; of Sensorial Qualities; of Memory; of Imagination; of Intellect; of Sentiments and Passions; of Will; of Natural Character; of Morbid States. In Part II. the author devotes four chapters to a discussion of the Laws of Heredity, the titles being: "Are there Laws of Heredity?" the "Laws of Heredity;" "Essays in Statistics" (containing a criticism of Galton's great work); "Exceptions to the Law of Heredity." Part III. shows the dependence of psychological upon physiological heredity. In Part IV. we have chapters on "Heredity and the Law of Evolution;" "The Psychological Consequences of Heredity;" "Moral Consequences;" "Social Consequences."

ANNUAL REPORT UPON THE SURVEYS AND EXPLORATIONS WEST OF THE ONE HUNDREDTH MERIDIAN. By Lieutenant GEORGE M. WHEELER, Corps of Engineers, U. S. A. With a Map showing the Areas surveyed up to the Close of the Field Season of 1873.

THIS is a pamphlet of 130 pages, issued from the Government Printing-Office, being Appendix F F of the Annual Report of the Chief of Engineers for 1874. It contains the report of Lieutenant Wheeler, in charge of the expedition, together with the reports of scientific researches made in connection with the survey. In addition to topographical work proper, the survey combines the establishment of numerous points astronomically; observations in meteorology and hypsometry; investigations in geology, mineralogy, and natural history; together with the collection of many other facts bearing upon the industries and resources of the regions traversed.

NOTES ON THE NATURAL HISTORY OF PORTIONS OF MONTANA AND DAKOTA.

THIS is a pamphlet of 61 pages, emanating from the Boston Society of Natural History, and is the substance of a report made to the Secretary of War on the collections made by the Northern Pacific Railroad Expedition of 1873, by J. A. Allen, naturalist of the expedition. It comprises a description of the mammals, birds, reptiles, plants, and butterflies, met with in their route from the Missouri River to the Yellowstone, between the 46th and 47th parallels, and the 100th and 109th meridians.

EIGHTH ANNUAL REPORT OF THE BOARD OF TRUSTEES OF THE BUILDING FUND OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA TO THE CONTRIBUTORS TO THE FUND. January, 1875.

THIS Report gives the list of subscribers from December, 1865, to December, 1874, as 461, of whom 39 are ladies. The total subscription is given at $203,965.24. This building fund is the result of a call made in 1865 for means to provide a new building, as their former limited space was becoming inconveniently crowded by new collections. The new building was begun July 9, 1872, on the north wing, which is expected to be ready to receive its collections in time for the Centennial, if the now nearly-exhausted treasury be sufficiently replenished for that purpose, an appeal for which is made in this Report.

ON THE MURIDÆ. By Dr. ELLIOT COUES, U. S. A. Reissued with Additions from the Proceedings of the Academy of Natural Sciences of Philadelphia, 1874.

THE present pamphlet of 28 pages is the first of a series of preliminary zoological reports to be elaborated from the material secured by the United States Commission for the survey of the northern boundary, and of which Dr. Coues was the naturalist. The ground covered is the northern border of the Territories of Dakota and Montana, along the parallel of 49°, from the Red River of the North to the Rocky Mountains.

ENGLISH GRAMMAR. By the Rev. RICHARD MORRIS, LL. D. 115 pp. 18mo. Price, cloth, 40 cents; paper, 30 cents. Macmillan & Co., 1875.

THIS little book is the first of a forthcoming series of "Primers of History and Literature," edited by J. R. Green, M. A., Examiner in the School of Modern History at Oxford. It presents in a handy and concise form the practical principles of English grammar, together with much information seldom found in grammars of greater pretensions.

PRELIMINARY REPORT UPON INVERTEBRATE FOSSILS COLLECTED BY THE EXPEDITIONS OF 1871, 1872, AND 1873, WITH DESCRIPTIONS OF NEW SPECIES. By C. A. WHITE, M.D. Government Printing-Office, Washington, 1874. 27 pages.

THIS preliminary report upon invertebrate fossils collected by Lieutenant Wheeler's expedition is made in order that the expedition may obtain due credit for priority of discovery, as nearly all the species noted are new. The pamphlet contains a full description, together with location, of some forty new invertebrate fossils.

MIGRANTS AND SAILORS CONSIDERED IN THEIR RELATION TO THE PUBLIC HEALTH. From Reports and Papers of the American Public Health Association.

THIS pamphlet, of 21 pages, comprises two papers: *A.* "Some Defects in the Immigration Service; Suggestions of Remedy therefor, with Reference to the Sanitary In-

terests of the Country. By John M. Woodworth, M. D., Supervising Surgeon United States Marine Hospital Service." *B.* "Sailors as Propagators of Disease;" Abstract of a paper entitled "The Hygiene of the Forecastle." By Heber Smith, M. D., Surgeon-in-charge United States Marine Hospital Service, Port of New York. The latter author gives diagrams of some representative forecastles, the sight of which is enough to condemn them. He shows how many of the gravest diseases are introduced and disseminated through communities to a greater extent by sailors than by any other agencies.

PUBLICATIONS RECEIVED.

An Analysis of the Life-form in Art. By Harrison Allen, M. D. Pp. 71. Philadelphia: McCalla & Stavely.

The Next Phase of Civil Progress. Pp. 43. New York: Dutton & Co.

The Glacial Epoch of our Globe. By Alexander Braun. Pp. 40. Price, 25 cents. Boston: Estes & Lauriat.

Protection and Free Trade. By Isaac Butts. Pp. 190. Price, $1.25. New York: Putnams' Sons.

Comparison of Certain Theories of Solar Structure with Observation. By S. P. Langley. Pp. 9.

Water in the Treatment of Disease. By V. Zolnowski, M. D. Pp. 39.

Vital Statistics and the "Military Reconstruction" of Louisiana. By S. E. Chaillé, M. D. Pp. 20.

Flora of Nebraska. By S. Aughey, Ph. D. Pp. 87.

Our Currency. By J. G. Drew. Pp. 43. Price, 20 cents. New York: Hinton & Co.

Irredeemable Paper Currency. Abridged from J. S. Mill's "Principles of Political Economy." Pp. 51. Price, 20 cents. New York: Hinton & Co.

The Cremation Theory of Specie Resumption. By David A. Wells. Pp. 19.

Measurement of Air-Angle of Microscope-Objectives. By R. B. Folles. Pp. 8.

Elements of Embryology (Foster & Balfour), Macmillan.

Elements of Mechanics (Nystrom), Porter & Coates, Philadelphia.

Birds of the Northwest (Coues), Government Printing-Office.

Improvement of Health (Knight), Putnams.

Lectures on the Teeth (Chase), Gray, Baker & Co., St. Louis.

Catechism of the Locomotive (Forney), *Railroad Gazette*, New York.

Maintenance of Health (Fothergill), Putnams.

New Manual of Physiology (Küss, Duval, and Amory), Campbell, Boston.

Philosophy of Breeding (Sturtevant), Wright & Potter, Boston.

Composition of the Ground-Atmosphere (Nichols), Wright & Potter, Boston.

Brooklyn Journal of Education.

Population of an Apple-Tree (Packard), Estes & Lauriat.

Geological Survey of Alabama (1874).

Physical Features of Minnesota River Valley (Warren).

The Mammoth Cave and Some of its Animals (Putnams).

The Family Nemophidæ (Putnams).

Stevens Institute of Technology (1874).

MISCELLANY.

The Fog-Signal Question.—The elaborate articles on "The Atmosphere in Relation to Fog-Signaling," by Prof. Tyndall, which appeared in our March and April numbers, embodied the interesting results of a new and important research, and have attracted much attention, both on the part of our men of science and of many unscientific readers. There has been some dissent from his views, but Prof. Tyndall is quite easy about that. In a recent private letter he says: "A copy of the report of the United States Light-house Board, for 1874, has just reached me. I read certain portions of it with regret, but the questions it raises may be safely left to the judgment of the scientific men of the United States."

A New Order of Mammals.—At a recent meeting of the Connecticut Academy, Prof. O. C. Marsh called attention to the very peculiar character of the extinct animal type, *Tillotherium*. So remarkable, indeed, are these characters that Prof. Marsh considers them sufficient to constitute a new order, for which he proposes the name *Tillodontia*. In *Tillotherium*, the type of the proposed new order, the skull has the same general form as in the bears, but in its structure it resembles that of the ungulates. The molar teeth are of the ungulate type, and in each jaw there is a pair of large scalpriform incisors, as in rodents. The articulation of the lower jaw with the skull corresponds to that in ungulates. The skeleton mostly resembles that of carnivores, especially the *Ursidæ*, but the scaphoid and lunar bones are not united, and there is a third trochanter on the femur. The feet are plantigrade, like those of the bears. Thus these singular animals combine the characters of three distinct groups—carnivores, ungulates, and rodents. The order comprises two distinct families—*Tillotheridæ*, in which the large incisors grew from persistent pulps, while the molars have roots; and *Stylinodontidæ*, in which all the teeth are rootless.

Animal Intelligence.—The following remarkable examples of animal intelligence are sent us by correspondents who vouch for their truth: A lady living in this city relates that the house occupied by herself and family became so infested with rats that, in the failure of all other means, they were obliged to resort to poison to exterminate them. Phosphorus-paste was used, spread thickly over meat, which was then placed where the rats could readily get at it. Pursuing this plan for a long time, they were surprised to find that, while the meat regularly disappeared, the rats remained, their numbers apparently increasing instead of diminishing. One day a man in charge of an adjoining stable asked who was trying to poison rats, and, being told, replied, "the rats are too smart for you." He led the lady to the alley alongside the house, where there was a hydrant, the nozzle of which being broken off, left the water constantly running. Under the hydrant they saw several pieces of meat, some partially covered with, and others entirely destitute of, any traces of the phosphorus-paste. After watching some time, the lady actually saw the rats not only eat the washed meat, but carry the coated pieces carefully in their mouths from her back-door around into the alley, and deposit them under the running stream of the hydrant. Our correspondent says that the rats may not have known the character of the coating on the meat, but that their course argues a knowledge of the properties of water, and a power of adapting means to ends, akin to reason.

An esteemed friend writes us of a dog, that had been savagely set upon by a neighbor's dog, rousing up with a growl when the circumstance was spoken of in his presence. This was noticed, and, on repeating the circumstances, when the neighbor's name and that of his dog were mentioned, the growling was repeated. No effort was made to attract the dog's attention, and it was easy to excite the animal at any time by mentioning these names in his hearing.

A lady in Troy has a terrier, whose ability to understand what is said to him seems remarkable. The lady sent him one day to drive some chickens out of the yard, but doing it roughly the lady said, "See, some of the chickens are little, you must be careful not to hurt them." The dog immediately flew at the large ones, but drove the little ones with great care, and always afterward observed the same caution. This terrier attended church regularly with his mistress, but one Sunday another dog attracted his attention in church, and he ran out, afterward returning to the pew. After getting home the lady said, "Whiskey was naughty to-day; he mustn't go to church any more." The dog hung his head and went to his bed. He made no attempt to go to church that afternoon nor ever again, though ready to go anywhere else.

The Deep-Sea Bottom.—Prof. W. B. Carpenter, in a paper recently published in *Nature*, dissents from the conclusions of Prof. Wyville Thomson, that the organisms *Globigerinæ*, whose shells compose the ooze of the deep-sea bottom, live and multiply in the *upper waters only*. He has

found the water taken from 750 fathoms depth, and just above the ooze upon the bottom, turbid from the presence of multitudes of young *Globigerinæ*. The evidence is satisfactory to him that they live and propagate on the sea-bottom, as well as near the surface—that the young rise to the surface in the earlier stages of their existence, and become inhabitants of the upper waters, and in their adult stage sink to the bottom in consequence of the increasing thickness of their shells.

The cause of their sinking, therefore, is not death of the creatures, but weight of their shells. The thickening consists in a deposit of calcareous matter upon the outside of the proper wall after the creatures' full growth, which not only increases the weight, but alters the contour of the shell.

Prof. Carpenter cites the fact, noticed by himself, that, in cold areas of the seabed north of Scotland, no *Globigerinæ* were found, while the warm areas adjoining are covered with this peculiar ooze to an unknown depth. Why is this, he asks, if the surface only is their habitat, where the temperature of the cold and warm areas is the same?

Priestleyana.—The recent celebrations at Northumberland and Birmingham of the centenary of the discovery of oxygen by Dr. Priestley brought out many curious incidents in his career, and numberless anecdotes; we select the following as characteristic:

While he was minister at Leeds, a poor woman, who labored under the delusion that she was possessed by a devil, applied to him to take away the evil spirit which tormented her. The doctor attentively listened to her statement, and endeavored to convince her that she was mistaken. All his efforts proving unavailing, he desired her to call the next day, and, in the mean time, he would consider her case. On the morrow the unhappy woman was punctual in her attendance. His electrical apparatus being in readiness, with great gravity he desired the woman to stand upon the stool with glass legs, at the same time putting into her hand a brass chain connected with the conductor, and, having charged her plentifully with electricity, he told her very seriously to take particular notice of what he did. He then took up a discharger and applied it to her arm, when the escape of the electricity gave her a pretty strong shock. "There," said she, "the devil's gone; I saw him go off in that blue flame, and he gave me such a jerk as he went off! I have at last got rid of him, and I am now quite comfortable."

The destruction of Dr. Priestley's house and laboratory, by the riotous mob, at Birmingham in 1791, proved most disastrous, and the maddened crowd met with little opposition. "There was a small attempt by a few people to drive off the rabble, but they were compelled to show their heels by a shower of brickbats." The following amusing doggerel poem, which was published at the time, refers to this incident:

"The famous Dr. Priestley
Though he preached to admiration,
Yet he never could persuade
The unruly cavalcade
Not to show their detestation.

"They burned down both the meetings,
His manuscripts and papers,
And they swore it in their wrath
That they would not leave him worth
A single farthing-taper.—

"His house and all the utensils,
Out-offices and stable;
Nor durst the doctor stay,
But prudently got away,
And rejoiced that he was able."

The following epitaph, having reference to Dr. Priestley's peculiar religious views, was composed, before his death, by Rev. David Davis, one of the wits of the time. Dr. Priestley is said to have laughed heartily over it.

"Here lie at rest
In oaken chest
Together packed most nicely,
The bones and brains,
Flesh, blood, and veins,
And *soul*, of Dr. Priestley."

—Prof. H. C. Bolton, in *American Chemist*.

Effects of Compressed Air.—From Bert's researches it appears that meat does not oxidize and putrefy in compressed air—merely undergoing a change of color, consistency, and taste. But, on the other hand, muscular and nervous excitability disappear very rapidly in compressed air.

Thus the conditions of the two phenomena are different. Again, certain fermentations may be arrested by oxygen at high pressure; the mycoderma of vinegar is destroyed or killed by the action of compressed air. Wine may be preserved from acetous fermentation by submitting it to compressed air. It is necessary, then, to distinguish in fermentation various phenomena belonging to chemical actions, and those belonging to the action of ferments, properly so called. M. Bert adds that compressed air stops the putrefaction of meat even where the latter has been impregnated with putrid germs.

Viniculture in California.—This was the subject of a paper recently read before the California Academy of Sciences by Dr. James Blake. The author analyzed the juice of four different varieties of grapes, grown in the vineyard of the California Vinicultural Society at Sonoma, viz., the Zinfindel, the Reimer, the Riessling, and the Mission grape. The last-named grape was introduced into California by the Franciscan missionaries, during the Spanish domination; the others are recent importations. The method of analysis was to ascertain the specific gravity of the juice, which was then heated, to coagulate the albuminous matters, and filtered through a Bunsen filter. Then the juice was brought up to the original quantity, and neutralized with a standard solution of potash or ammonia, so as to ascertain the amount of free acid. Another portion was evaporated to about one-third, mixed with alcohol and ether to precipitate the tartrates, and the ether and alcohol distilled off from the filtered juice, which was then neutralized to ascertain the amount of malic acid. The amount of sugar, as indicated by the specific gravity, was controlled by direct analysis of a portion of the juice, cleared by acetate of lead, by means of Fehling's copper-test. The result was as follows:

GRAPES.	Sp. Gr.	Sugar.	Free Acid.	Malic Acid.
Zinfindel.....	1072	16.6	1.78	0.60
Riessling.....	1068	18.7	1.10	0.57
Reimer	1057	14.0	1.20	0.80
Mission grape...	1068	21.5	0.60	0.11

The small proportion of malic acid in the Mission grape explains the absence of aroma in the wine. The author attributes the failure to make first-class wine in California to two causes, viz.: 1. Bad quality of the grapes; 2. Injudicious choice of soil for vineyards.

"The Successor of Steam."—An article under the above title, by Dr. H. Beins, of Gröningen, has appeared in the *Chemical News*. The successor of steam is liquid carbonic acid. The author says: "For many years I have, with the collaboration of my brother, who is director of the Netherlands Soda Manufactory at Amsterdam, considered the question, 'How to transpose heat into mechanical power more advantageously than it is done in our common steam and other engines?' It occurred to me to make an experiment to see what degree the tension of the carbonic acid given off by natrium bicarbonate would amount to when heated in a closed space. We were surprised and much gratified to find that when natrium bicarbonate in a dry, pulverized state, or in a watery solution, is heated in a closed space, a part of the carbonic acid is given off and condensed in a not-heated portion of that space, so that, at a temperature of 300° or 400° C., liquid carbonic acid can be distilled out of this salt with a tension of from 50 to 60 atmospheres."

He then points out certain highly-important aspects of this fact: 1. Carbonic acid of high tension, and, in particular, liquid carbonic acid, is an excellent motive-power for small and great industries. The weight of a carbonic-acid engine for ships, with 100 horse-power, and combustible stores for 240 hours, would be one-fifth less than the weight of a steam-engine of the same power. The former engine, too, will occupy less space. "I have experimentally found," he writes, "that a carbonic-acid engine is easily constructed. Taps and joints can be made to answer perfectly. A year ago I filled a tube of hammered copper with carbonic acid of 50 atmospheres, and not the least loss is as yet observed. Wrought metals are therefore not permeable for gases of that tension. For the great industries the carbonic-acid engine can, in almost every case, substitute the steam-engine. For the small industries, especially

for engines working with intermissions and during brief spaces of time, the property of liquid carbonic acid, of being always ready for work, is of much importance. By this same property, and since the mechanical equivalent of electricity is very small, such an engine is a very fit and cheap source of electrical light. My method of compression furnishes easily the required tension for the conveyance of letters in tubes, and the modern break-apparatus for railways." Further, the author suggests that his discovery might be turned to account in artillery, and in the construction of submarine vessels.

New Eocene Mammals. — Prof. Marsh is now contributing to the *American Journal of Science* a series of notices on new and hitherto undescribed mammals found in the Tertiary strata of the West. In the March number of the *Journal* he describes some new forms of quadrumana, a species of his new order *Tillodontia*, three species of rhinoceros, a new species of *Brontotherium*, and various other extinct animal forms. Among the quadrumana here described, we have a new genus, *Lemuravus*, closely resembling the lemurs in skeleton and in the general structure of the skull. The species *L. distans* was about the size of the largest squirrels. During the late raid into the "Bad Lands" of Nebraska, Prof. Marsh found the lower jaw of a monkey, which indicated an animal about the size of a coati; it is the first specimen of the order *Primates* found in that region, and forms a new genus and species—*Laopithecus robustus*. The order *Tillodontia* is represented by the new species *Tillotherium fodiens*. The animals of this order are among the most remarkable yet discovered in American strata. They seem to combine characters of several distinct groups, viz., carnivores, ungulates, and rodents. The *Tillotherium fodiens* would appear to have been about two-thirds as large as a tapir. The rhinoceroses described are *Diceratherium armatum*, *D. nanum*, and *D. advenum*. These animals had a pair of horns placed transversely, as in modern ruminants, as is clearly indicated by large, bony protuberances on the anterior portion of the nasal bones. The *D. armatum* would appear to have been about two-thirds as large as the Indian rhinoceros; the *D. nanum* was scarcely more than half the bulk of the preceding; while the *D. advenum* was half the bulk of the Indian rhinoceros. The new genus of *Brontotheridæ* is denominated *Anisacodon*, and it is represented by the new species *A. montanus*. According to the author, this family consists of four well-marked genera, viz., titanotherium, megacerops, brontotherium, and anisacodon. The name *Diplacodon elatus* is given to a new genus and species intermediate between *Limnohyus* and *Brontotherium*. Two new equine species from the Miocene are described, and three new species allied to the collared peccary.

Premature Criticism. — Mr. Proctor, in the *English Mechanic*, calls attention to a very curious piece of literary criticism occurring, of all places in the world, in the *Atlantic Monthly*. The critic is very severe in his sentence upon "The Sun," "The Orbs around Us," and other works by Mr. Proctor, but the value of his judgment is impaired by the evidence Mr. Proctor furnishes to show that it is not based on a knowledge of what is contained in the books. Among the works thus adversely criticised is "Other Suns than Ours." Of this Mr. Proctor says: "It may be as bad as he says; it may be 'trash,' and it may 'confirm the evil prognostic of its title,' but he might have waited till it was published. Three years ago, when it was half written, it was announced for early publication. Unfortunately for my critic (but fortunately for me), he has been led to suppose that the work accordingly appeared, and might safely be abused. But a great pressure of work prevented me from completing some stellar observations necessary for its illustration, and the MS. still lies unfinished in my desk. What a savage literary Herod a man must be who would thus slaughter the book unborn!"

Fossils in Trap-Rock.—The occurrence of fossils in trap-rock, though not uncommon, still awaits a satisfactory explanation. Mr. E. A. Wünsch, writing in a late number of *Nature*, mentions several instances of the presence of both plant and animal remains

in such rocks, and then has the following as to how they came there: "There is every probability that originally the enveloping matrix must have reached the fossils in the shape of volcanic ash, or, more likely still, in the shape of a thick fluid sediment enveloping the trunks of the trees as they stood erect, with their broken branches, leaves, and fruit scattered around them. We have numerous instances of ash-beds overlying limestone-beds containing corals, and I suspect Mr. Honeyman's '*trap rock in a fluid state*' would resolve itself into a rock of the nature above indicated; at all events, it would be very interesting to geologists on this side to receive specimens for closer examination. With regard to the possibility of fossils being inclosed and preserved in fluid lava, I may mention that when at Catania, in 1867, I was informed by Prof. Sylvestri that oak-trees on Mount Etna, when overtaken by lava-streams, are not actually annihilated, but the lava forms a sort of hollow cylinder around the trees, in which they are carbonized, and the silex contained in the wood collects in a fused mass at the bottom of the trunk. Such fused masses I met with at the foot of some of the stems of trees excavated by me at Arran, and numerous pebbles, evidently derived from the same source, are to be picked up on the shore between the Fallen Rocks and the Scriden at the north end of Arran."

Curious Method of capturing Musk-rats.—The *American Sportsman* describes the ingenious method followed by trappers in catching musk-rats: These animals often travel great distances under ice. In their winter excursions to their feeding-grounds they take in breath at starting, and remain under water as long as they can. They then rise to the ice and exhale the air in their lungs; this remains in bubbles against the under surface of the ice. They wait till this air recovers oxygen from the water and ice, and then, reinhaling it, go on till the operation has to be repeated. In this way they can travel almost any distance, and live any length of time, under the ice. The trapper takes advantage of this habit. When the marshes and ponds where musk-rats abound are frozen over, and the ice is comparatively thin and clear, they can be seen swimming about beneath. Following one for some distance, the trapper sees it come up to renew its breath in the manner described. After the animal has exhaled, and before it has time to take in the reoxygenized air in the bubbles again, he strikes with his hatchet directly over it, scattering the bubbles, and driving the musk-rat away. In this case the rat drowns in swimming a few rods, and the trapper, cutting a hole in the ice, takes it out. Mink, otter, and beaver, travel under the ice in the same way, and hunters, it is, stated, frequently take otters in the same manner.

Education of Telegraph-Operators.—In Holland the applicant for apprenticeship in a telegraph-office is required to present a thesis in Dutch; to be acquainted with French, English, and German; to know the first principles of arithmetic, common and decimal fractions, and the metrical system of weights and measures; to have mastered the rudiments of algebra and geometry, and in geography to be familiar with the situation of the various countries and principal towns. When an apprentice applies for the position of a telegraphist of the third class, he is required to pass an examination in magnetism, electro-magnetism, etc.—in short, to prove his familiarity with every detail of telegraph administration. Remarking on this, the *Journal of the Telegraph* says that in this country the person who enters the telegraphic service "must certainly know his telegraphic letters and make them correctly; must write a clear hand; must have a knowledge of circuits and office connections; and must be informed respecting the company's rules. Yet these simple requirements are objected to. 'I fear,' says the manager of a large office, 'if this were required here, I should be left almost alone.' We ask, 'Can this ignorance of the commonest knowledge of a great business be true?' We fear it is."

How Water is injured by Organic Matter.—In a recent work entitled "Scientific Conversations," by M. Porville, of Paris, the reason why organic matter becomes a dangerous constituent of water is thus set forth: "How does organic matter become dangerous? We must not believe that it

constitutes, as is superficially said, a toxic element. The phenomenon is more complex. The organic matter in suspension or in solution creates in the water a peculiar medium, suitable for the development of exceedingly small beings of the genus *Vibrio*. It is no longer mere water—it is a world of microscopic animals and plants which are born, live, and increase with bewildering rapidity. The infusoria find in the water calcareous, magnesian, and ammoniacal salts, and their maintenance is thus secure. Drink a drop of this liquid, and you swallow millions of minute beings. But there are vibrios and vibrios. There are those which are capable of setting up putrefaction in our tissues. These are our enemies, often our mortal enemies. Let water be placed in contact with organic remains capable of nourishing these malignant vibrios, and it at once becomes more dangerous than any poison."

A Motherly Fish.—There is found, in the clear, pebbly streams which descend to the plains from the mountain-ranges of Trinidad, a small fish of the perch tribe, which in its great care for its young presents a singular contrast to all other known fishes. A writer in *Nature* states that on one occasion, as he approached the water for the purpose of taking his morning bath, his attention was attracted by the eccentric movements of one of these little fishes. In general they are very shy, scudding off into deep water on the approach of man; now, however, when a hand was put into the water, the fish darted forward again and again, striking the hand with considerable force. The explanation of this conduct was soon found: in a small hollow near by, about the size of half an egg, artistically excavated in the bright quartz-sand, a multitude of tiny fish were seen huddled together. They had apparently been very recently hatched, and were no larger than common house-flies; the parent-fish kept jealous watch over her progeny, resenting every attempt to touch them. Returning to the same spot on the following day, the writer of this narrative searched there in vain for the fish and her young. At length, however, a few yards farther up stream the parent was discovered guarding her fry with zealous care in a cavity similarly scooped out in the coarse sand; any attempt to introduce one's finger into the nest was vigorously opposed by the watchful mother.

Arsenical Colors.—A Swedish chemist, Dr. Hamberg, has made some important researches on the arsenical coloring-matters of wall-paper. The paper of the room in which the experiments were conducted had a light-green ground, with an ornamental pattern of brownish-yellow color; this yellow was probably derived from an ochre, but the green resembled Schweinfurt green, and was strongly arsenical. An arrangement was made for drawing a current of air through a series of U-shaped and bulbed tubes, suspended on the wall. The passage of air was continued from July 16th to August 16th, and it was calculated that during this time about 2,160,000 cubic centimetres of air had traversed the system of tubes. Some of the tubes had been plugged with cotton-wool, while others contained a solution of nitrate of silver, and at the termination of the experiment the contents of the tubes were separately examined. The results showed that there had been an arsenical exhalation. The family living in the house had never suffered any marked injury from breathing this poisoned air; but Dr. Hamberg, after sleeping in a room by the side of the apartment in which his experiments were made, and with the door open, frequently experienced, on the following morning, a sense of heaviness in the head, and a general feeling of weariness.

Distribution of Water in Aquaria.—In constructing aquaria it is important to bear in mind the fact that, for aquatic animals which breathe without lungs, the value of water does not depend so much on its amount, as upon its distribution in such a manner that it may be sufficiently oxygenated by contact with the atmosphere. Mr. W. A. Lloyd, who calls attention to this matter in the *Zoologist*, says that when the amount of surface of water exposed to air, as well as the actual quantity of water, is regulated according to the known requirements of the animals to be kept, the well-being of the creatures is promoted, and the

cost of constructing and maintaining aquaria considerably diminished. This principle is applied in the transportation of living aquarium animals to considerable distances. Take, for example, a fish packed in damp, freshly-gathered sea-weed. Its gills are kept wet by such very thin films of water that their thinness, otherwise shallowness, enables them to be constantly oxygenated by contact with the atmospheric air. Thus the gill-filaments are kept wet and separate from one another, and the blood flows uninterruptedly through them, being aërated as it does so.

The Origin of the Potato.—Mr. Meehan, of Philadelphia, has for eight years cultivated *Solanum Fendleri*, a solanaceous plant which has much in common with the potato (*Solanum tuberosum*). His object was to ascertain whether the former could be transformed into the latter by cultivation, and so to settle the vexed question of the origin of our common esculent tuber. It was not till last year that the plant began to vary in the direction of the potato. Previously, the tubers were round, about the size of a large bullet, and rugose from the imperfect tube-cells on the surface. Last season, however, the roots began to resemble those of the potato. They were oval and compressed, and one was an inch wide and two inches long, with a clear, semi-transluscent skin, as in the more delicate potatoes. Mr. Meehan, however, does not expect to develop potatoes from his wild solanum; according to him the facts so far obtained do no more than suggest the possibility of the unity of origin of the *Solanum Fendleri* and the *S. tuberosum*.

Cultivation of Jute in the South.—The cultivation of jute in the southern portion of the United States seems destined to become, at no distant day, a highly-profitable industry. Notwithstanding the many difficulties and drawbacks of the past season—deluging rains, overflows of rivers, and droughts—it was expected that the harvest in Louisiana would be satisfactory. In a letter to the Department of Agriculture, Mr. Emile Lefranc, of New Orleans, President of the Southern Ramie Association, describes some of the fields as splendid, growing eight feet high, and as thick as wheat. The forthcoming report of the Department will contain a description, with illustrative drawings, of Lefranc's jute-cleaning machine. This machine will produce over a ton of clean fibre per day, with four attendants only. It cleans jute, ramie, and okra radically, and without waste, and it is believed that hemp and flax may also be treated with it with equally satisfactory results.

NOTES.

S. Augusto Guattari, of Castellamare, Italy, has devised an improvement in pneumatic telegraphs, consisting of an instrument which will serve either as a transmitter or receiver. By means of two such instruments, placed at different stations and connected by a single air-conducting tube, messages may be transmitted in either direction. There is but one dial, which serves to indicate both the signals sent and received, so that the same instrument is made to answer both purposes, thereby dispensing with one of the two required in all other pneumatic telegraphs, and lessening the cost of apparatus. The invention has been patented here.

Dr. John Edward Gray, F. R. S., naturalist of the British Museum, died March 6th, in the seventy-fifth year of his age. He was a voluminous writer on zoological and botanical subjects. He was connected with the Natural History Department of the British Museum for over fifty years. In addition to his strictly scientific work, he took part in the discussion of various questions of social importance, such as public education, prison discipline, the postage system, and the organization of museums and galleries of art.

Died at Bonn, on the 17th of February, Prof. Friedrich Wilhelm August Argelander, the celebrated astronomer. Deceased was born in 1790, and in 1820 became the official assistant of Bessel at the Königsberg Observatory. From 1845 till his death, he was in charge of the observatory of the Bonn University. His "Celestial Atlas," lately published, ranks among the best works of its kind.

"The isolated study of any thing in natural history is a fruitful source of error. . . . . No single experiment in physiology is worth any thing."—Dr. Jeffries Wyman.

A manual is to be prepared for the use of the British Arctic Expedition of next summer, consisting of reprints of papers in the transactions of learned societies not otherwise accessible, and other materials, the ob-

ject being to furnish an exact view of the state of existing knowledge of Greenland and the surrounding seas.

In Osage County, Kansas, the fruit-trees which had been stripped by the grasshoppers all put forth leaves again, and many of them bloomed with double flowers; most of the embryo fruit was double.

From the researches of Charles Violette on the distribution of the saccharine and saline principles in the beet, it appears that the former increase considerably by arithmetical progression from the collar to the point of the root. The saline constituents do not show a regular variation in quantity from one end of the beet to the other, still the chlorides are more abundant at the collar than at the point.

The Agassiz Memorial Fund has been accepted by the President and Fellows of Harvard College, for the use of the Museum of Comparative Zoology founded in that university by Agassiz. The continuous growth of the museum is thus assured.

"Mumbo Jumbo" is commonly supposed to be the proper name of an African god; in reality he is a sort of policeman, an institution peculiar to the Mandingoes on the river Gambia. A traveler in Africa informs us that he is the terror of the Mandingo women, for whose special benefit and discipline he has been established. A strong, athletic man, dressed from head to foot in dry plantain-leaves, appears when invoked by an injured husband. He goes through all sorts of antics and pantomime among the assembled villagers, all of whom are there under pain of suspicion. Suddenly he pounces like a tiger upon the offending wife, and thrashes her severely with a long rod with which he is armed. The crowd, especially the women in it, drown her cries with jeers and laughs. In other parts of Africa a similar domestic policeman exists.

M. d'Omalius d'Halloy, the distinguished Belgian geologist, died at Liége, January 15th, at the age of ninety-two years. He was the author of several text-books on geology, as also of numerous memoirs contributed to learned societies and scientific periodicals.

An aquarium-car containing 300,000 fishes for California waters was wrecked last year *en route*, and its living freight precipitated into the Elkhorn River. Another attempt at introducing into the streams of the Pacific slope some of the valuable food-fishes of the Atlantic coast was more successful. Mr. Livingston Stone, of the United States Fish Commission, started from Albany on the 25th of June with about 40,000 young shad. Of these, 5,000 were placed in the Jordan River, a tributary of the Great Salt Lake, and the remainder in the Sacramento.

The monthly report of the Department of Agriculture states that last year the "chinch-bug," which usually restricts its ravages to growing Indian-corn, in Johnson County, Missouri, attacked potato-vines, and even the tobacco-plant.

In the peat-bogs of Northwestern Germany a peat-cutting machine is employed, consisting of a large, flat-bottomed steam-vessel, which, when set to work, is able to cut a canal 20 ft. in breadth and 6 ft. in depth, while proceeding at the rate of from 10 to 12 ft. per hour. The soil thus cut out is lifted into the vessel by steam-power, there thoroughly ground, and deposited, by means of a pipe running out of the side of the vessel, on the bank of the canal, where it is subsequently cut into bricks and dried. By this method about 55 tons of very good peat may be manufactured per day. A similar machine is also in use in Canada.

A medical officer of the British Navy recommends that each member of the projected Polar Expedition have fitted to his *sacrum* a flat spirit-lamp, from which a tube should pass up the spine beneath the clothes to the occiput, so as to maintain the heat of the trunk and vital organs!

By invitation of the Senatus Academicus of the University of Edinburgh, Prof. Huxley will perform the duties of the chair of Natural History in the coming summer session, in the place of Prof. Wyville Thomson, who is absent with the Challenger Expedition.

A quarterly review of scientific psychology and philosophy will be issued in London in the course of the present year. It will discuss many subjects at present but little attended to in psychological journals, such as language, primitive culture, comparative psychology, etc. The title of the new periodical will be *Mind*.

A monument is about to be erected in Stockholm to Scheele, the great Swedish chemist, who discovered tartaric acid, chlorine, baryta, and glycerine; he also discovered oxygen in 1777 in the course of his own independent researches, though the honor of prior discovery belongs to Priestley. A monument is also to be erected in Brussels, to Quetelet, the illustrious statistician.

In the Freedmen's Mission Chapel at Green Cove Spring, Florida, a circular saw, about three feet in diameter, serves as a bell to call the people to prayers. The saw is suspended from a rafter, and it is sounded by means of a wooden mallet. This "bell" is heard, in calm weather, at the distance of a mile and a half.

CONVENTION OF THE TOADSTOOL FAMILY.